The
ENGINEERS' DIGEST

REVIEW OF WORLD ENGINEERING PROGRESS

VOL. XX No. 11 NOVEMBER, 1959

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5	2.24	3.16	3.88	4.77	5.48	6.71	7.75	10.0
7.5	1.82	2.56	3.16	3.65	4.47	5.48	6.32	8.17
10	1.58	2.24	2.74	3.16	3.88	4.74	5.48	7.07
15	1.29	1.83	2.24	2.58	3.16	3.87	4.47	5.78
25	1.00	1.41	1.73	2.00	2.45	3.00	3.46	4.47
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150	.408	.575	.707	.818	1.00	1.22	1.41	1.82
200	.354	.500	.612	.707	.866	1.06	1.22	1.58
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2,500	.100	.141	.173	.200	.245	.300	.346	.448
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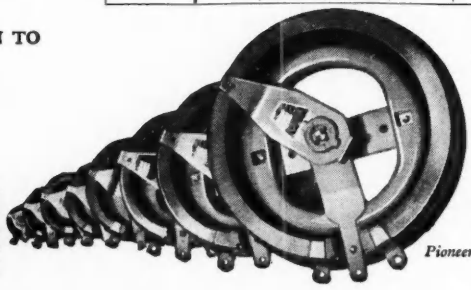

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FRANCE
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ITALY
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Annual Subscription Rates:
£2 2s. 0d. in the Sterling area, $7.50 in the Dollar area

Printed in Gt. Britain by THE ALCUIN PRESS, Welwyn Garden City, Hertfordshire, and published monthly by the proprietors, ENGINEERS' DIGEST LTD., 120 Wigmore Street, London, W.1.

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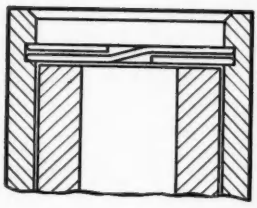

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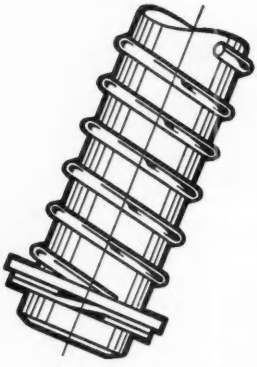

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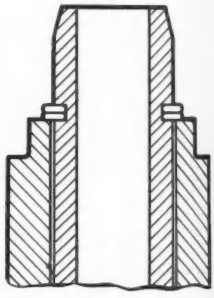

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THE BLUE PAGES

A QUICK GLANCE AT THE LATEST TECHNICAL DEVELOPMENTS THROUGHOUT THE WORLD

• *MANUFACTURE OF COMPLEX MAGNETIC MATERIALS*

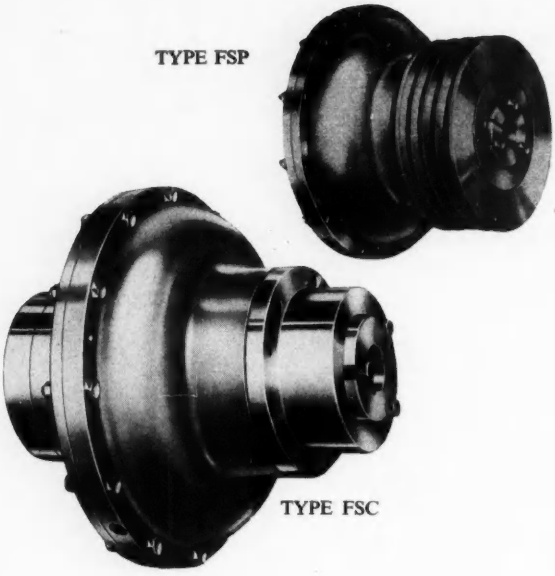
Magnetic materials mainly consisting of iron, and alloyed with nickel, cobalt, or other metals, have a high saturation. However, if these high-saturation materials are in powdered form, mixed with oxidic magnetic materials, and if the mixture is processed by powder-metallurgy methods, it is practically impossible to prevent the particles of the metallic components of the mixture from being short-circuited magnetically and electrically. In this connection, it is true that cores are already known in which such short-circuiting of iron particles is prevented by providing them with a layer of aluminium oxide to insulate them from each other, but this non-magnetic insulating layer causes dilution of the magnetic iron-particle phase and hence a reduction in magnetic properties. It is stated, however, that a recently patented manufacturing process prevents this magnetic and electrical short-circuiting and brings about an improvement in the magnetic properties of a complex magnetic material comprising a metallic component and a ferrite. Basically, the process comprises manufacturing the material in such a way that the particles of the metallic material are externally oxidized and then mixed with metal oxides capable of entering into the formation of magnetic ferrites, after which the mixture is subjected to a sintering process, so that the oxide coating on the metallic particles forms, in conjunction with the metal oxides, the ferrite component. Oxidation of the metal can be carried out by means of water or steam, so as to produce superficial rusting, by subjecting the finely divided metal to a gentle oxidizing treatment at an elevated temperature in a reaction chamber containing air, pure oxygen, steam, etc., or by entraining it in a stream of these gases. In the production of permanent magnets, the oxidation of the powdered metallic phase should preferably be continued until not only the metal-oxide complex phase, e.g., a ferrite, but also the remaining metallic residue itself shows permanent-magnet properties.

• *IMPROVED METHOD OF MANUFACTURING DIAMONDS FROM GRAPHITE*

Although industrial diamonds have been produced in the U.S.A. for some time, they are of very small size. It is therefore interesting to note that a recently patented Dutch process is intended for the production of diamonds of relatively large size and that high dynamic pressures, as opposed to the more conventional high static pressures, are used. For this purpose, high dynamic pressure is provided by a suitable explosive and is made to act on a target containing graphite, which is transformed wholly or partly into diamond by the high pressure generated. In order to decrease the " seed-forming " energy required, crystallization seeds, e.g., splinters of diamond or some structurally related substance, can be embedded in the target. The explosive may be in the form of a shaped charge provided with a liner of graphite, so that a jet resulting from the detonation of the charge is directed at the target. Alternatively, the explosive may consist of a conductor of very small cross-section, detonation being effected by the discharge of a charged capacitor through the conductor, causing high-pressure shock-waves to impinge on the target. The process may be carried out in a vacuum, in air, or in some other atmosphere, and, if desired, the target can be preheated. Also, the housing in which the target is located can be subjected to an external counterpressure. It is claimed that this process provides a simple, cheap, and rapid method of producing diamonds of comparatively large size, as opposed to the very small diamonds produced by the American process, which uses heavy equipment and operates at a static pressure of approximately 140,000 atm and a temperature of 2700°C.

• *PRODUCTION OF POROUS FILTER TUBES OF PLASTIC MATERIAL*

A convenient form of filter for liquids and gases consists of a tube or series of tubes of porous material, through the walls of which the liquid or gas is caused to pass. Examples of such filters are the unglazed ceramic tubes used in some water filters and the cloth bags used in some air filters. However, certain thermoplastic polymers, such as polyvinyl chloride, polythene, and polystyrene, possess excellent resistance to chemical attack and can be used in the presence of corrosive liquids and gases. As a result, they are eminently suitable as filtering media, and it is interesting to note that a recently patented process is concerned with the production of porous plastic tubes, using heat alone, without the application of pressure, to obtain from



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thermoplastic polymer powders a sintered material which has satisfactory strength, while maintaining a volume porosity of from 35 to 45%. At the same time, serious discoloration or depolymerization of the plastic is avoided. In this process, the powder is placed in the space between the outer and inner dies of a mould which is then heated to a temperature sufficient to cause sintering only of the particles, with consequent shrinkage, leaving a clearance around the inner die. In carrying out the process, hot oil is initially circulated through ports or passages in the outer die. Thereafter, hot oil is also circulated through the inner die. Cool oil is then circulated, first through the inner die only, after which the inner die is withdrawn from the sintered porous tube, and then through the outer die to facilitate removal of the sintered tube. The pore size of the sintered material can be varied by changing the particle size of the powder employed; for example, a powdered polymer with an average particle size of 50 microns produces a material with an average pore size equivalent to 25 microns. In addition to their use as filter media, porous tubes of this type lend themselves to other applications, e.g., as tubular retainers for the active material in the positive plates of lead-acid secondary batteries.

● *IMPROVED RESISTANCE MELTING FURNACES FOR QUARTZ SAND*

In many conventional resistance furnaces for melting quartz sand into quartz, the sand flows downwards between horizontal rod electrodes, and it has been found that these rods, which are normally made of graphite, are subject to intensive wear, often necessitating their replacement after only a few hours of operation. As a result of the consequent interruption of the melting process, it is often impossible to produce large blocks of molten material, especially in great lengths. Apparently, a layer of silicon carbide is formed on the surface of the graphite rods during melting, and this layer is then wholly or partly torn off on coming into contact with the melt. This continual repetition of forming and tearing off the surface layers of silicon carbide rapidly causes a marked decrease in the cross-section of the rods. It is now claimed, however, that this defect can be overcome by completely enclosing each rod in a suitable tubular cover, with an annular space between them, thereby screening the rods from contact with the material being melted and thus avoiding their premature destruction by formation and removal of layers of silicon carbide. In this way, their life is increased, enabling larger uniform blocks of melt, and blocks of greater length, to be produced, and permitting a continuous melting process to be carried out. The protective cover does not carry electric current and can be of any suitable shape to provide good flow of the mass of melt, e.g., circular or oval. The cover is made from a highly refractory non-metallic material of good heat conductivity, such as oxides, nitrides, or borides of zirconium or titanium, or from silicon carbide. The cover can even be made of graphite, if desired. In this case, it is true that it will become coated with a layer of silicon carbide but, as it does not carry the heating current and hence does not attain the high surface temperature of the heating rods themselves, the silicon carbide layer will remain firm and will not be torn off. In fact, in this case, the silicon carbide layer actually forms a protective coating which increases the life of the cover.

● *METHOD OF PRODUCING ULTRA-HIGH-STRENGTH STEELS*

The development has been announced of a new heat-treating and mechanical-working process for steel, making it possible to achieve tensile-strength values exceeding 400,000 psi while still retaining good ductility. Broadly speaking, the method consists of extremely heavy mechanical working of the steel in the range between 800 and 1050°F, following by transforming to martensite and then tempering. It is an essential feature of the process that the decomposition of austenite to non-martensitic products is minimized, as there are indications that these products are detrimental, and this is effected by choosing steels with a high hardenability and by limiting the temperature range for deformation to the austenitic "bay" from which the steel is quenched to martensite. Microstructure, carbon content, and the degree of deformation are significant variables. The process has already been applied satisfactorily to steels containing 0·48 and 0·63% C, with about 2·9% Cr, 1·6% Ni, 0·75% Mn, 0·4% Mo, and 1·5% Si. In tests on these steels, deformed 90%, the higher-carbon steel exhibited a greater strength over the complete tempering range. Thus, an ultimate tensile strength of 464,000 psi was observed for this steel after tempering at 212°F, while the yield strength rose sharply and uniformly above 350°F to about 400,000 psi after tempering at 600°F. The elongation of the lower-carbon steel was generally greater than that of the higher-carbon steel, this trend in increasing strength and reduced ductility with increasing carbon content being similar to that observed in conventionally heat-treated martensitic steels. The process results in a fine martensitic structure, one of the reasons being that deformation increases the grain boundaries and the number of localities where platelets of martensite can form, while the microstresses introduced promote the formation of more (and hence smaller) martensite platelets. Also, bending of the austenitic lattice, as well as heavy de-

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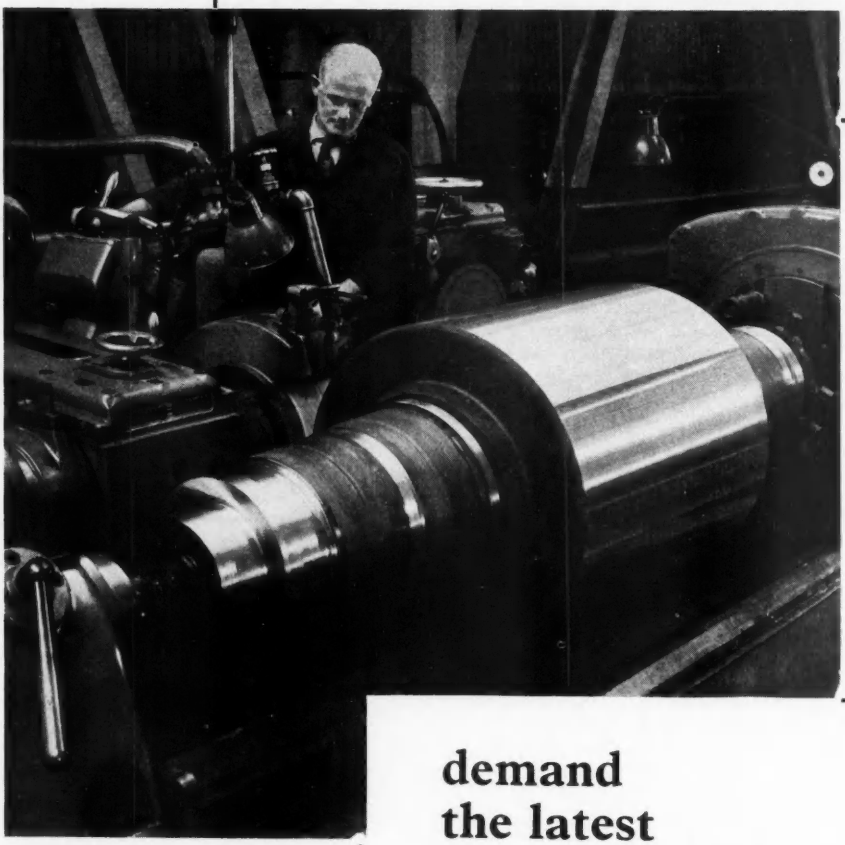

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formation of the austenitic slip-bands, limits the growth of the platelets. Moreover, the austenitic grains are stretched out, further reducing the cross-section and blocking the growth of the martensite.

• *FLAMELESS BURNER*

In a new flameless burner, a blower drives a fuel-gas or fuel-oil vapour and air through a porous burner wall made of a catalytic material, no gas discharge ports being used. The burner has the shape of a microporous tube open at one end and sealed at the other. Air and fuel injected at the open end are forced through the pores, and combustion reaction takes place on the catalytic surface last encountered by the mixture. After ignition, a blue flame momentarily flares up and then settles down to a steady-combustion state, characterized by a sharply defined plasma layer which persists on the surface of the reactor. The surface-plasma temperature depends largely on the choice of fuel and oxidizer (for natural gas and air, the temperature may exceed 2000°F), and the catalyst temperature depends on the geometric configuration of the burner. Completeness of combustion depends on the catalyst, i.e., on composition and temperature, and combustion is said to be extremely stable. Even when the amount of air injected is the theoretical minimum for combustion, the carbon monoxide generated is claimed to remain well within the limits imposed by modern safety standards. The fuel rate to the reactor can be varied over a considerable range. Under high feed rates, the reactor is self-limiting in power output and plasma temperature and for this reason does not destroy itself, even when input is extremely high. Heating efficiency is said to be exceptionally high, 75% or more of the heat output being transferred directly by heat radiation. The microscopically fine structure of the tube wall prevents flashback under all operating conditions. Furthermore, since the reactors are incandescent bodies, they cannot be extinguished by draughts.

• *ELECTROMAGNETIC FORCE-MEASURING DEVICE*

It is known that the torsional stress in a hollow shaft can be measured electromagnetically by magnetizing the shaft circularly with a winding threaded through and linked with the shaft and by measuring, by means of another winding around the shaft, the axial flux component due to torsional stress, this method being based on the so-called first inverse Wiedeman effect. There is also a second inverse Wiedeman effect, which implies that axial magnetization causes a circular flux in a shaft subjected to torsion; this can also be utilized for measuring torsional stress and in many cases is the more practicable method. Both inverse Wiedeman effects can be used for measuring forces by fitting the hollow shaft with levers on which the forces can act. It would be natural to fit the levers to the hollow shaft by welding, but this, however, gives rise to considerable welding stresses. Owing to magnetostriction not only in the hollow shaft, but also in the weld and the levers, these welding stresses give rise to a deformation of the magnetic field, so that no proportionality exists between the instrument reading and the force to be measured. In a recent patent, it is therefore proposed to use a hollow shaft with flanges to which the levers are attached and to make the flanges and the shaft in one piece, so that they form a single bobbin-shaped member of homogeneous material. The flanges are so dimensioned that the joints between them and the levers are substantially outside the path of the magnetic flux enclosed by the winding connected to the measuring device. In this connection, the winding connected to the measuring instrument is threaded through and linked with the hollow shaft, while the second winding, which is excited by alternating current, is wound around the shaft.

• *STEPPING TRANSISTOR ELEMENT*

Persistent research extending over a number of years is reported to have resulted in the development of a functional semiconductor device which acts like a gas stepping tube, i.e., a digital counter capable of carrying out functions usually performed by complex circuitry or relay devices. This new transistor structure provides electron transfer analogous with gas discharge in an electron tube, electron transfer taking place by the emission of minority carriers from a *pn* junction which is common to all *pn-pn* elements. In theory, the new semiconductor device has some similarity with the gas tube, in which transfer of electrons between elements is provided by the diffusion of ions from the discharge region to the adjacent electrode. Thus, as in the case of the gas tube, the stepping transistor structure provides a preferential direction of electron transfer by using an asymmetrical geometry. However, in the gas tube, current transfer is accomplished by arranging the electrode to which transfer is to be made close to a discharge region, whereas close proximity between elements is not necessary in the stepping transistor, since potential has to be transferred. Thus, single four-terminal stages can be encapsulated separately and interconnected externally, though several stages can also be integrated in one unit. The four-terminal device acts as a pulse-controlled on-off switch and may have applications beyond its use in stepping circuits. For example, versatile decoders can be made by using one

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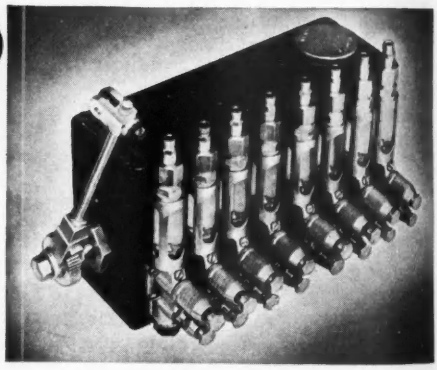

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element to drive two others. As a prototype of an integrated device, a stepping transistor with four stages or elements has been made, and it is claimed that devices of this kind have operated at speeds up to one million pulses per second. It is expected that, with improved designs, even higher operational speeds may be obtained.

• *REDUCING THE CORROSIVE PROPERTIES OF FLUE GASES*

It is well known that combustion gases, e.g., flue gases from boilers, contain acid constituents such as sulphur trioxide which cause corrosion when they come into contact with metal surfaces such as economizers or air heaters at the outlet of boilers, furnaces, or other heat-exchanger units. However, according to a recent patent, it has been found that the corrosive properties of combustion gases may be reduced by introducing into the gases a solution of some alkali-metal salt in order to neutralize some of their acid constituents, examples of suitable salts being sodium carbonate, sodium hydroxide, potassium carbonate, and potassium hydroxide. preferably used in amounts up to 0·2% by weight of the fuel consumed. It is recommended that the alkali-metal salt solution be introduced into the stream of combustion gases in the form of a fine mist or spray at any point where the salts will be able to mix with the flue gases before the zone where corrosion is anticipated. Injection should not, however, be made so near to the combustion chamber that the salts will deposit on the heat-exchange surfaces and cause serious fouling. In one case, a 15% aqueous solution of sodium carbonate, equivalent to 0·008% by weight of the fuel consumed, was injected with the aid of compressed air as a very fine mist from four nozzles in the flue-gas duct between the secondary air heater and the primary air heater of an oil-fired boiler. The rate of wastage of the metal tubes at the air inlet to the primary air heater due to corrosion was reduced from 0·004 in. thickness per 1000 hours to less than 0·002 in.

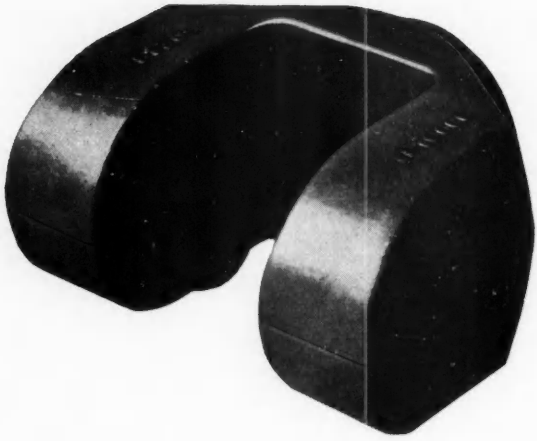
• *LOW-FREQUENCY INDUCTION HEATING OF BILLETS*

Although the use of low frequency, e.g., 25 to 60 cps, for the induction heating of billets or other metallic charges has a number of advantages over high-frequency methods, it has the particular disadvantage that it is not easy to provide low-frequency equipment which will produce a uniform heating pattern over the entire length of a billet. It is now stated, however, that this difficulty has been overcome by recently patented equipment in which provision is made to vary the pattern of the magnetic flux inside the coil. This is effected by incorporating a flux-concentrating core of magnetic material which extends into the space inside the coil from one end and whose position is adjustable, together with a number of take-off taps distributed over the portion of the coil along which the magnetic core is adjustable. An additional means of varying the pattern of the magnetic flux inside the coil can consist of providing more turns per unit length in the coil winding at some locations than at others. For instance, the coil winding can have fewer turns per unit length near the portion over which the take-off taps are distributed than at the remainder of the coil. Furthermore, the support for the charge can also be adjusted to vary the relative positions of the charge and coil, and this also contitutes an additional means of varying the pattern of the magnetic flux inside the charge.

• *HIGH-PURITY ALUMINA CERAMIC*

A polycrystalline material made from powdered aluminium oxide has been developed which readily transmits light, withstands much higher temperatures than most ceramics at present in use, and can be pressed into any shape desired. Closely related to sapphires and rubies, which are made of single-crystal aluminium oxide, the new polycrystalline form of the same compound is reported to be superior to these gems in its ability to withstand high temperatures without deforming. It has the composition of a ceramic, the structure of a metal, and a light-transmitting ability approaching that of glass. Because of the elimination of the small or " bubble " pores normally found in ceramic materials, it is possible, for instance, to read through a sheet of the material when laid flat upon a piece of paper. At greater distances it appears translucent, resembling frosted glass. At least 90% of the light in the visible spectrum is transmitted through the material. The basic material is fine-grain high-purity alumina, pressed at room temperature and then fired at temperatures which are higher than usual for ceramics, the metal-like structure resulting from the direct bonding of the crystals to each other, with neither pores nor glass matrix between them. A useful application would be in high-intensity incandescent and discharge lamps, now limited in some cases by the heat resistance of their transparent envelopes. Thus, fused quartz, often used for high-temperature lamps, performs satisfactorily up to a temperature of 1800°F, whereas the new material is stable at temperatures up to nearly 3600°F.

For a further selection of items, please see our "Minidigest" section on pages A2 and A4



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REVIEW OF WORLD ENGINEERING PROGRESS

VOL. XX No. 11 NOVEMBER, 1959

Progress in Electron-Beam Welding

By G. BURTON, JR., and W. L. FRANKHOUSER. (From *Welding Journal, U.S.A.*, Vol. 38, No. 10, October 1959, pp. 401s–409s, 14 illustrations)

WELDING operations with a beam of electrons at more than 50 kV were performed by Steigerwald in 1950, while Stohr, of the Atomic Energy Commission of France, used an electron beam to join metals in 1955 and first announced details of his experiments in 1957. Since then, considerable interest has been aroused in the process in England, France, and the U.S.A. An electron-beam welding machine has been operated for some time in the U.S.A., and some of the results obtained with it have already been reported.* The present report is primarily concerned with a description of the experimental results achieved with a high-voltage machine having a maximum beam power of 1 kW and a voltage up to 100 kV, particularly in connection with the welding of Zircaloy-2.

WELD PENETRATION IN ZIRCALOY-2

The electron-beam process provides an opportunity for concentration of weld heat to a degree never before attained in welding equipment. For example, it has been possible, by operating at 90 kV and 5 mA, to concentrate the electron beam at the workpiece to a focal-spot diameter of approximately 0·010 in., i.e., equivalent to about 5750 kW/sq in. To make an equivalent weld penetration in Zircaloy-2 by the conventional tungsten-arc inert-atmosphere-chamber welding process, 10 V and 270 A were required, which is equivalent to only 55 kW/sq in., assuming a "spot size" of 0·250 in. The actual energy consumed in making each of these welds was 45 and 180 watt-minutes per inch of weld respectively. Thus, for equivalent weld penetration in Zircaloy-2, the tungsten-arc welding process required four times the energy and melted approximately twice the volume of metal as the electron-beam welding process. Appreciable thermal energy is dissipated at the arc and into the inert shielding gas by the tungsten-arc process, while the thermal energy of the electron beam in the absence of a surrounding thermal conducting atmosphere is applied directly to the surface of the workpiece.

The effect of the extreme concentration of thermal energy is also manifested three-dimensionally by relatively deep weld penetration, accompanied by a narrow weld-fusion and heat-affected zone.

The ability to achieve extreme concentration of thermal energy at the weld is possible only with high-voltage-type electron-beam equipment. Three electron guns, which operated between 2 and 15 kV, have been tested, several other units have been examined at other installations. In all cases, the depth/width ratio of the weld-fusion zone has been no more than equivalent to that obtained with the tungsten-arc welding process. At the same time, consistent and uniform weld penetration in Zircaloy-2 was limited to 0·050 in. maximum, and slow welding speeds; multiple welding passes and comparatively large total energy inputs were required for low-voltage equipment, while a depth of 0·250 in. at a welding speed of 10 ipm has been obtained with the 1-kW high-voltage welding machine.

A survey of the complete operational range of the high-voltage 1-kW electron-beam welding machine was performed to determine the depth of weld penetration which could be achieved and to establish optimum welding conditions which would result in predictable weld penetration for use in fabrication processes. A convenient welding specimen was selected, which consisted of four bars of vacuum-melted Zircaloy-2, 4 in. long × 0·500 in. wide × 0·250 in. thick. These four bars were clamped tightly together in a fixture to simulate a continuous 4 × 2-in. plate. Ten welds per specimen were made in the direction perpendicular to the butt joints. Subsequent to welding, the four bars were separated, and the depth of weld fusion was determined at the fractured surfaces with the aid of optical measuring equipment. Six readings were obtained per weld pass, with two at each interface. Four weld passes were made at a welding speed of 15 ipm for each electron-beam power setting, determined by all possible combinations of voltage (50, 60, 70, 80, 90, and 100 kV) and current (2, 4, 6, 8, and 10 mA). From the results obtained, the following conclusions have been made:—

(1) Within the useful operating range for the 1-kW welding machine, between 50 and 100 kW, weld penetration may be obtained between 0·020 and 0·150 in. at a welding speed of 15 ipm, as shown in Fig. 1.

(2) At each setting of voltage, there is an optimum value for the electron-beam current which results in the maximum weld depth for that particular voltage. Since it is desirable to obtain a specific degree of penetration at minimum heat input (i.e., beam power) to the work, it is advantageous to operate at this value of beam current. For the complete range of voltage investigated, the optimum beam current is about 5 mA at 50 kV, increasing uniformly to about 8 mA at 100 kV.

(3) As anticipated, weld penetration is reduced by increasing welding speed but, even at 30 ipm, up to 0·100-in. depth of fusion can be readily achieved. Fig. 2 shows the general effects of different welding speeds on weld-penetration depth with different electron-beam currents and voltages.

(4) A 2:1 depth/width ratio has been achieved at 100 kV and 4 mA, as indicated in Fig. 3, which shows the depth/width ratios of the weld fusion zone for different currents and voltages at a welding speed of 15 ipm. It should be noted that a depth/width ratio as

The Engineers' Digest, No. 4, 1958, pp. 141–142.

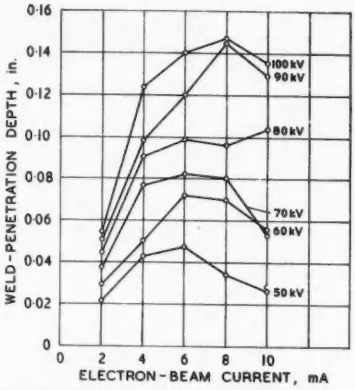


Fig. 1. Weld-penetration depth in Zircaloy-2 with different electron-beam currents and voltages at a welding speed of 15 ipm.

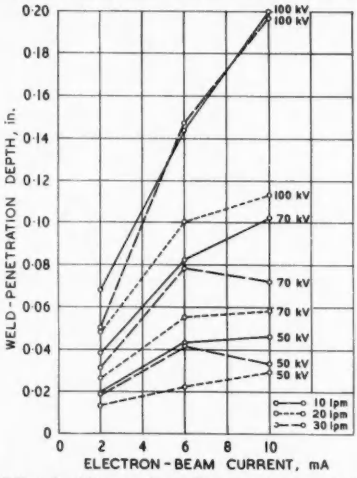


Fig. 2. Effect of welding speed on weld-penetration depth in Zircaloy-2 with different electron-beam currents and voltages.

high as 3-1 has been achieved in Zircaloy-2 over a small range of beam power by adjustments in the location of the anode, cathode, and cathode filament.

(5) A strong positive correlation exists between electron-beam power and reproducibility of weld penetration. This correlation is further supported by the difficulty experienced by the operator in setting and maintaining the control settings for the higher electron-beam powers. The exact source of this variability has not yet been determined with certainty, but appears to be a functional characteristic of the laboratory-model welding machine under investigation.

Although all these penetration data were obtained on relatively short welds, work is in progress which shows that remarkably uniform weld penetration can be maintained over longer seam lengths, up to at least 30 in.

Chemical Analyses

Alloys melted in a vacuum of the order of 1 micron Hg or less have been shown to be subject to compositional changes, owing to vaporization of the more volatile constituents. This effect is very significant in the electron-beam melting process and must be compensated by starting with a suitably enriched base melting alloy. However, the quality of material evaporated is dependent not only on the vapour pressures of the elements and compounds, but also on the time at temperature and the degree of superheating. For electron-beam welding with the 1-kW welding machine, no evidence has been found to substantiate the occurrence of a change in composition due to the welding process.

Table I: Composition of Zircaloy-2

Constituent	Welded Material	Base Material
Iron	0·112%	0·113%
Chromium	0·106%	0·112%
Nickel	0·048%	0·048%
Tin	1·410%	1·390%
Oxygen	860 ppm	850 ppm
Nitrogen	35 ppm	20 ppm
Hydrogen	16 ppm	19 ppm

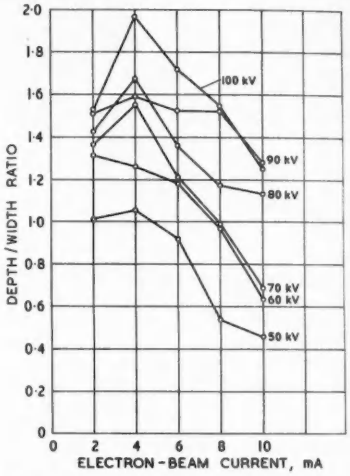


Fig. 3. Depth/width ratio of the weld fusion zone in Zircaloy-2 with different electron-beam currents and voltages at a welding speed of 15 ipm.

Table I shows the chemical analysis of electron-beam-welded Zircaloy-2 and also of the adjacent unaffected base material. Allowing for normal analytical chemistry variations, no significant differences can be observed for any of the elements investigated.

Metallography and Hardness

The microstructure of typical electron-beam-welded Zircaloy-2 is similar to that of tungsten-arc fusion-welded material. The edge of the fusion zone has a beta-quenched structure with a very fine prior-beta grain size, indicating that this material was heated to the vicinity of the lower limit of the beta region and remained at temperature for a very short duration. Finally, the outer edge of the heat-affected zone shows an alpha + prior-beta grain structure, indicating the disruptive effects of heat applied to the typical hot-worked structure of the base-plate material.

These structures are normal for welded Zircaloy-2, but evidence the fact that minimum thermal energy was applied to the butt joint to achieve fusion. In welds made with a surplus of thermal energy, the prior-beta grain size of the fusion zone is appreciably larger, owing to the characteristic rapid growth of the beta grains in Zircaloy-

2 with time. The narrowness of the fusion and heat-affected zones also attests to the efficient use of the applied energy.

The increase in hardness through the weld zones is attributed to a supersaturated solid-solution condition resulting from the rapid cooling of the weld.

Corrosion Resistance

Zircaloy-2 used for cladding and structural components in pressurized water-cooled and moderated nuclear reactors is usually subjected to simulated service-testing to determine resistance to corrosion. This test consists of sealing specimens in an autoclave and subjecting them to high-purity steam or water at elevated temperature and pressure. The steam test accelerates the corrosion rate and usually reveals defective material after a shorter period of testing than water. Corrosion results from the oxidation of the zirconium alloy, the oxygen being provided by the high-temperature water or steam. Since the ZrO_2 formed is a tightly adhering film, the oxidation rate may be measured as a function of gain in weight.

To determine whether Zircaloy-2 electron-beam-welded material retained its normal corrosion resistance, coupons, machined to $1 \times 1\frac{1}{2} \times 0.100$ in., were fabricated and then welded over at least 90% of their surface area. The coupons were divided into two groups, one being placed in water at 680°F, and the other in steam at 750°F. The weight-gain data accumulated at 3, 14, and 28 days were recorded, together with the expected weight gains for reactor-grade Zircaloy-2.

The three-day weight-gain data obtained were of value in establishing a trend, but judgment of corrosion resistance should not be made until at least 28 days of testing. The 14- and 28-day test data revealed no significant departures for the weld metal from normally expected corrosion rates, and it can be concluded from these partially completed tests that electron-beam-welded Zircaloy-2 is satisfactory for nuclear-reactor applications. These tests will be continued for a total of 128 days.

Mechanical Properties

The tensile-strength properties of welded Zircaloy-2 were investigated, using subsize tensile specimens having a 1-in. gauge length and an 0.125-in. gauge diameter. The tensile specimens were machined from solid plates on which 100% penetration welds had been made, and were oriented both longitudinally and transversely to the welds. Reference standard specimens were machined from the plate adjacent to the welds and parallel to the rolling direction, but sufficiently distant to preclude heat effects. All specimens were annealed at 1110°F prior to testing. The testing temperatures were selected to correspond with the range of operating temperatures for pressurized water reactors. The specimens of welded material in general showed slightly higher ultimate and yield strengths and correspondingly lower reduction in area and elongation than the hot-rolled plate material. These differences are the result of the microstructural changes brought about by welding.

Impact-strength test specimens were also fabricated from solid-plate Zircaloy-2 in which 100% penetration welds had been made, the notch being aligned with the central axis of the weld. The specimens measured $0.2 \times 0.2 \times 1$ in., and were annealed at 1110°F prior to fracturing. The Izod test position was used for these tests. The comparative test values obtained (Fig. 4) revealed that electron-beam welded Zircaloy-2 had a

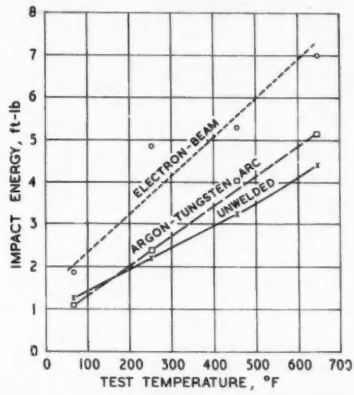


Fig. 4. Izod impact strength of electron-beam-welded, argon-tungsten arc-welded, and standard unwelded specimens of Zircaloy-2.

higher impact strength than the tungsten-arc fusion-welded material. This was probably the result of the narrow fusion zone, which allowed considerable deformation to occur adjacent to the weld zone. The length direction of the standard unwelded specimens was oriented parallel to the direction of rolling. These data are of value only on a comparative basis, since total separation of the bars into two pieces occurred only in the room-temperature tests.

Process Applications

The unique characteristics of the high-voltage electron-beam welding process point to several process applications, i.e., (1) the welding of refractory metals, (2) the welding of metals with relatively high thermal conductivity, (3) the welding of highly reactive metals, and (4) the making of certain " special-situation " welds not possible or inadequately performed with conventional welding processes. The first two are considered potential applications on the basis of the extreme concentration of thermal energy, which makes possible the deep narrow fusion zone and narrow heat-affected zone. This reduction in size of the heat-affected zone may also be valuable in welding dissimilar metals.

The potential advantages envisioned with the high-voltage electron-beam welding process for nuclear fuel-assembly fabrication have been extrapolated into cost estimates for subassembly and cluster fabrication. A substantial reduction in process costs is required to amortize the current high capital costs of the welding equipment if the process is to be considered competitive with the conventional welding process. By taking advantage of the use of a vacuum, it appears probable that fuel elements containing oxide-corrosion films from previous corrosion tests can be welded directly into subassemblies and then into clusters without removal of the corrosion film. By taking full advantage of the overall reduced energy input to make a weld of given depth and of the considerably reduced weld shrinkage and consequent distortion, it should be possible to weld subassemblies without benefit of the fuel-element spacers which are ordinarily used to maintain spacing between elements during welding and which are subsequently removed.

Furthermore, it is anticipated that distortion due to fusion welds can be maintained at a level sufficiently low such that the machining operations on subassemblies

subsequent to welding will be minimized, and that straightening and sizing operations can be entirely eliminated. The ability to make deep-penetration welds with narrow fusion zones not only minimizes distortion, but also eliminates the need for multiple-pass welds with filler-wire additions to achieve heavy-joint sections of the type found in fuel assemblies and in fuel-assembly structural parts.

In order to pursue fully this programme for future applications in the field of welding, a second high-voltage welding machine has been purchased and is capable of welding at 150 kV with a maximum beam power of 2 kW. This unit will be mounted on a specially designed prototype production chamber, in which the largest nuclear-fuel assemblies can be processed, and a pilot-

(*Concluded on page 467*)

U. S. A.

Thermo-Mechanical Stress-Relieving of Aluminium Parts

By H. N. Hill, R. S. Barker, and L. A. Willey. (From *Metal Progress*, Vol. 76, No. 2, August 1959, pp. 73-76, 4 illustrations)

In a new method of relieving the residual stresses in quenched aluminium parts, particularly those of irregular shape, the quenched parts are first cooled to —320°F in liquid nitrogen and are then heated rapidly in a blast of steam. Since this technique is essentially the reverse of quenching, inasmuch as the parts are rapidly heated, rather than cooled, through an extensive temperature range, the stresses induced by previous quenching are reversed and are largely cancelled out.

Many commercial aluminium alloys attain their strength through heat treatment. While the specific treatment depends on the alloy, the part is usually quenched in water from about 900°F. Stresses occur because the surface cools faster than the centre, and temperature gradients spread throughout the part. When the bath temperature is finally reached, these gradients vanish but, in disappearing, they set up a system of residual stresses, the surface usually being in compression and the centre in tension. Stress magnitudes vary with alloy and severity of quench. Solution treatment is generally followed by precipitation hardening or ageing at 250° to 450°F. This treatment further enhances the strength, but has no marked effect on residual stresses.

Residual stresses can be relieved by heating or by mechanical deformation. However, heating is not practical for heat-treated alloys because temperatures high enough to relieve stresses lower the strength. Deformation by stretching is regularly applied to products of uniform cross-section, such as sheets, plates, and extruded shapes. Parts not suited to stretching, such as hand forgings and some die forgings, can be compressed. In the case of irregularly shaped parts, where these methods are impractical, the new method is therefore a useful means of relieving residual quenching stresses.

To be effective, the method, which has been designated " uphill quenching ", must produce temperature gradients large enough to cause local plastic deformations, without, however, employing temperatures high enough to affect the mechanical properties of the material. These requirements are met by cooling to a sub-zero temperature, followed by rapid reheating in a blast of steam, after which the component can be aged as prescribed for the specific alloy. The result of the " uphill " quench is a considerable reduction in residual stresses with virtually no effect on mechanical properties. The process has been termed a thermo-mechanical method to connote that, while the treatment is actually thermal, the relief of residual stresses is brought about by mechanical plastic deformation.

It should be noted that the use of hot-water jets or immersions in boiling water were found inadequate, only a blast of steam reducing residual stresses to the desired degree. Two features of the steam blast help to attain the required high heating rate, i.e., the heat of condensation of the steam, and the actual blast, which removes the condensate from the surface of the part being treated.

Cooling to —100°F, followed by rapid reheating with steam results in a reduction in stress level of about 50%, greater reductions being obtained with lower temperatures. The maximum temperature difference between surface and centre increases as the cooling temperature is lowered. The close relationship between the maximum temperature difference measured between surface and centre and the reduction in residual-stress level is shown in Fig. 1.

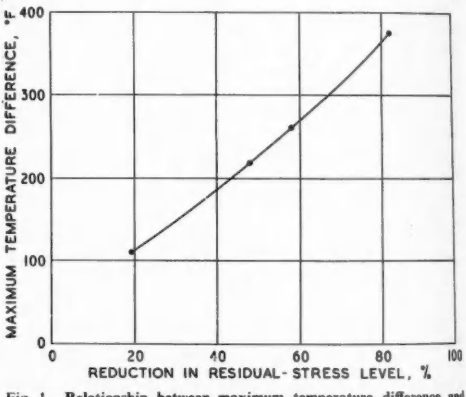


Fig. 1. **Relationship between maximum temperature difference and reduction in residual-stress level.**

For a given thermal gradient, the effectiveness of the method depends on the yield strength of the material. For this reason, the thermo-mechanical treatment must be applied before the yield strength has been raised by ageing. Tests have shown that the treatment is ineffective if applied to parts with a T6 temper and also that residual stresses can be induced in annealed material, i.e., in material without original residual stresses. It is therefore evident that the " uphill-quenching " method cannot be applied indiscriminately, and that it is intended only for those parts having appreciable residual stresses introduced by quenching.

Recycling was found to be ineffective, the same degree of stress-relief being obtained with one treatment as with five. Specimen thickness affects stress relief in that thicker materials are relieved to a greater degree.

Metal-Spraying under Protective Atmospheres

By W. E. Stanton*

During the spraying of all but the precious metals, a limited amount of oxidation occurs which takes the form of a thin envelope of oxide enclosing each sprayed metal particle. This reaction takes place partly in the flame, where some free oxygen is always present, and partly whilst the particles are carried in the spray stream. Further action occurs immediately after the impact of the particles with the surface being coated.

For many applications the resulting oxide content of the deposit does not detract from the efficacy of the coating. Anti-corrosive coatings of sprayed aluminium owe their resistance to attack partly to the network of inert oxide films formed during the process. On the other hand, oxide films are detrimental in protective coatings of metals such as nickel, since the oxides offer less resistance to chemical attack than the parent metals. As is to be expected, such coatings, when exposed to particularly corrosive environments, may fail prematurely owing to intergranular attack of the oxide films.

Many instances arise where it would appear to be advantageous to apply sprayed coatings free from oxide, and attempts have been made to produce such deposits by means of both molten metal and modified flame-spraying equipment. A method which is partially successful substitutes an inert gas for the compressed air normally used to form the spray in conventional gas spraying equipment. In this method it is impossible to avoid contamination from free oxygen at the melting-point zone and from air aspirated into the spray beam, with the result that the oxide content of the product is not materially reduced.

It has been suggested that an electric arc might be used for the continuous melting of metals in wire form, the molten metal again being atomized by a stream of air or inert gas. A considerable amount of experimental work on this basis has been undertaken, but experience has shown that the method is not at present readily adaptable for continuous operation by remote control—a condition which is essential for any process which must be performed in a totally enclosed system.

A patented British method entails melting the metal in the form of a rod or wire by electric induction heating, the rod or wire being fed coaxially through the turns of a work-coil which is energized by an alternative current at high frequency. With this arrangement, induced currents are set up at the surface of the metal, bringing about its fusion. An inert gas is directed onto the melting tip of the wire or rod in such a way that atomizing of the liquid metal is continuous, and the spray so formed is then projected onto a suitably prepared surface to produce an oxide-free sprayed coating. Metal powders may also be produced by this method by directing the spray onto a liquid surface, in which the particles become trapped and are collected as sludge. By a suitable arrangement of ducts and fabric filters, it is also possible to arrange for the dry collection of the powder. The particle size of the powder formed in this way is controlled by adjusting the propellant-gas pressure, which in turn determined its velocity for similar nozzle orifices. A high velocity produces extremely finely divided particles a few microns in diameter, whilst small pellets can be produced with gas at low velocity.

The process is carried out in a totally enclosed system and, for most economical working, the projecting gas is recirculated. The system is maintained at a pressure slightly above atmospheric, and there is therefore little danger of oxygen infiltration. Powder-producing plant is usually required for continuous operation and its design and construction are relatively simple. When collecting particles as sludge, provision must be made to expose continuously a fresh liquid surface to the spray stream. This is effected by means of an endless belt which passes at a predetermined speed first through a reservoir of liquid, and then in front of the spray beam. When dry powders are required, the collecting system is of necessity rather more bulky, since the particles must be carried in the gas stream until they have cooled to the solid state. Should the particles come into contact with a dry surface, even while in a semi-plastic condition, adhesion invariably results, giving a build-up of solid material.

Most metals when finely divided and unoxidized are extremely reactive, and will burn spontaneously, sometimes with explosive violence, when brought into contact with oxygen. Compounds containing oxygen are readily dissociated by these metals, and less violent, yet similar, reactions occur when they come into contact with compounds containing sulphur or the halogens. Extreme care is therefore necessary in the collection and subsequent handling of such powders.

Collection of the products as dry powders is rather more difficult than wet collection, since all the operations must be carried out under a reducing or neutral atmosphere. When collecting wet powders, the main consideration is the choice of a suitable liquid medium in which to suspend the powder. It must not react with the metal powder and must be unlikely to cause complications in subsequent processes. Dehydrated liquid paraffin is frequently used in the collection of powders of aluminium, nickel, and copper alloys.

A high-frequency atomizing plant of this type has been installed for the production of reactive aluminium powder. In this particular plant, current at high frequency is supplied from a generator having an output of 12 kW at a frequency of 450 kcs. The generator is housed in a building remote from the atomizing plant, from which high-frequency current is transmitted to the work-head by transradio coaxial cables. The work-head comprises an inductance and capacitor circuit which is tuned to resonate with the generator frequency, the inductance taking the form of a compact work-coil consisting of a few turns of rectangular copper tubing. The work coil is narrow at the centre (about $\frac{1}{2}$ in. in diameter), and its manufacture presents quite a difficult problem. Owing to the low inductance of the work-coil (about 0·2 microhenry) it is resonated locally by a capacitor of relatively high value.

This particular capacitor consists of approximately twenty mica capacitor units, each of 0·03 mF, connected in parallel and held in two layers between water-cooled clamping plates. Adjustment of the work circuit to obtain resonance with the generator is accomplished by the addition or removal of capacitor units. In order to maintain the capacitor at a uniform temperature, special oil circulation has been incorporated, the oil being cooled by water from the system built into the generator. For cooling the work-coil, water is supplied directly

*Metallisation Limited.

Fig. 1. Unetched photomicrograph of steel sprayed in air. (×100)

from the mains, since more than half the radio-frequency output power of the generator must be dissipated. A water-flow switch is fitted for tripping the high-tension supply if for any reason the water flow fails.

The metal to be atomized is in the form of $\frac{3}{16}$-in. o.d. wire, fed to the work-coil by a pair of rollers driven through a variable-speed gear and powered by an electric motor. A straightener is incorporated in the wire-feeding mechanism to ensure true alignment of the wire with the axis of the nozzle. As the wire emerges from the feed rollers, it first passes through a system of gas seals and then through the centre of a non-metallic nozzle. Although nozzles may be of alumina, porcelain, or almost any refractory material, experience has shown that certain plastics are particularly suitable for this purpose. The nozzle enters the work-coil for a distance of about $\frac{3}{16}$-in. and continuous melting of the wire occurs at a distance of $\frac{3}{8}$ in. from the nozzle tip.

The spray emerging from the coil is scarcely visible, even when spraying steel. This is quite different from the appearance of steel sprayed in air, in which case the individual particles become incandescent in flight. Oxidation accounts for the higher surface temperature of the particles sprayed in air, and it is not surprising that micro-examination of deposits sprayed in argon does not show the characteristic lamellar structure of metals sprayed in air.

Steels sprayed in air are generally much harder than the same metals in wrought form. When sprayed in argon, the hardness of steel approximates that of the wrought metal. Typical values for mild steel are 249 DPN when spraying in air, and 125 DPN when spraying in argon. The results confirm the theory, long held, that the increase in hardness obtained during spraying is directly connected with the oxide content.

In the unetched condition, no sprayed structure is visible. The same material sprayed in air clearly shows the oxide films outlining the sprayed particles (Fig. 1). When etched in 2% nital, the steel sprayed in argon consists of very small equiaxed grains (Fig. 2), but at a higher magnification (Fig. 3), some signs of laminations appear in places, probably indicating the termination of crystal growth in successively deposited particles.

Deposits of titanium, nickel, magnesium, and calcium may be applied with equal facility by the high-frequency argon process; investigations into the spraying of niobium, tantalum, and tungsten are proceeding. Photomicrographs of argon-sprayed titanium wire of doubtful purity are illustrated in Figs. 4 and 5. In Fig. 5, the acicular structure in part of the sprayed deposit can clearly be seen.

The future holds promise for the deposition of coatings of purities previously unobtainable. In its present form, however, the appartus has obvious limitations, both in the size of components that can be accommodated in the inert-gas chamber, and in the capital cost of the equipment and the present high cost of inert gases.

According to a recent report from Russia,* investigations have been made into metal-spraying under protective atmospheres other than argon. In these investigations, a low-carbon steel wire, about $\frac{3}{4}$ in. in diameter, was used, an electric current of 30 V, 100 A being employed to initiate melting of the steel particles,

Mashinostroitel, No. 6, 1959, pp. 45-46.

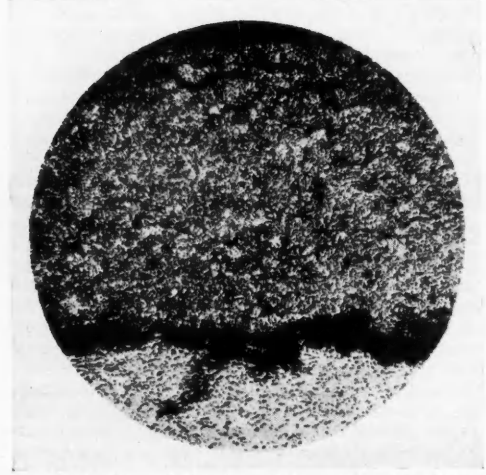


Fig. 2. Photomicrograph of steel sprayed in argon. Etched in 2% nital. (×100)

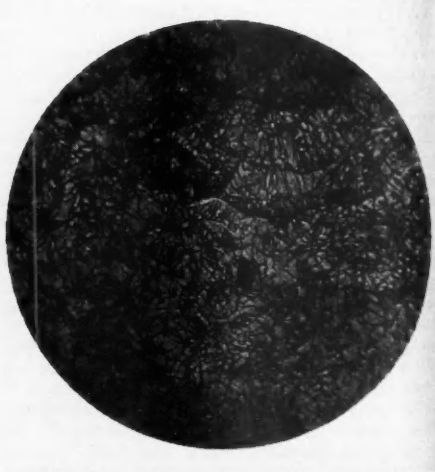


Fig. 3. Photomicrograph of steel sprayed in argon. Etched in 2% nital. (×325)

and the melting zone being kept at a distance of from 3 to 6 in. from the surface of the base metal. The surfaces of all specimens were carefully prepared by grit-blasting and, after spraying, the porosity, mechanical structures, microstructure, and the strength of the bond between the base metals and the deposits were examined. It is stated that the best results were obtained with a protective atmosphere consisting of blast-furnace gas containing 66% nitrogen, 20% carbon monoxide, 9% carbon dioxide, 2% hydrogen, and 3% water, supplied at a pressure of 5 atm. At the same time, it is claimed that relatively sound coatings were also obtained with the use of the exhaust gas from an internal combustion engine as the protective atmosphere, though in this case their strength was found to be inferior to that of coatings produced under blast-furnace gas.

In commenting on this investigation, it should be mentioned that it is true that the use of a by-product gas is obviously attractive, insofar as cost is concerned, but, as it is necessary to compress the gas to 5 atm, much of this advantage is lost. It should also be noted that, with a totally enclosed system, spent gas may be recirculated by feeding it back to the compressing unit and in this way the overall consumption, even of pure gases such as argon, might be reduced to an economic level. On the other hand, if the spray is open to atmosphere, special precautions must be taken to avoid fire or the explosion of the combustible gas used in this particular investigation, as well as its toxic effects on nearby personnel.

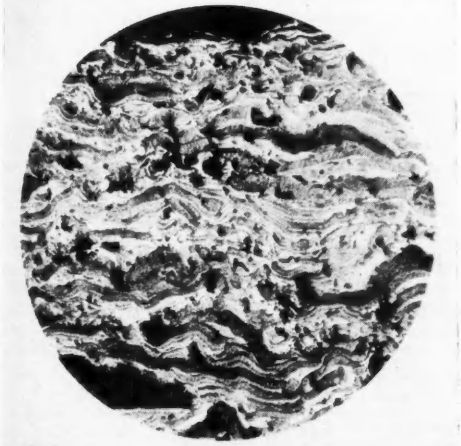


Fig. 4. Photomicrograph of argon-sprayed titanium wire of doubtful purity. Etched in HF/HNO_3 and water, and HF/HNO_3 and glycerine. (×65)

The deposits produced under by-product gas would certainly be substantially free from oxidation, if sprayed in the closed system, but the improvement would be less marked if spraying were carried out in the open, and unfortunately the Russian report does not mention whether the system used was closed or open. Also, it should be pointed out that an interesting factor which may have some influence on steel deposits is the formation of iron carbonyl and nitrides, both compounds being known to be produced on exposure of molten iron to high concentrations of carbon monoxide and nitrogen.

Tests have also been carried out in Russia in connection with the use of nitrogen as a protective atmosphere when spraying coatings of stainless steel, aluminium, and other metals. Nitrogen was considered to be especially suitable for protecting stainless steel, which does not easily absorb nitrogen. Moreover, the use of nitrogen greatly reduces the danger of intercrystalline corrosion, thereby improving the quality of the coatings. However, as the investigators point out, the use of nitrogen introduced a number of technological problems, particularly in connection with the extremely large quantity of nitrogen required, rendering its use uneconomical.

Fig. 5. Photomicrograph of argon-sprayed titanium wire of doubtful purity, showing acicular structure in part of the sprayed deposit. Etched in HF/HNO_3 and water, and HF/HNO_3 and glycerine. (×1000)

In an effort to reduce the amount of nitrogen required, these Russian tests were carried out with spray guns in which the diameter of the central nozzle was decreased, but it was found that this produced poor-quality coatings. However, it is claimed that a satisfactory solution was obtained with the use of a combined nitrogen/air jet supplied through two concentric nozzles to the melting zone, the protective atmosphere in this case comprising 94% nitrogen and 6% oxygen. With this protective atmosphere, it is stated that burn-out of chromium from stainless-steel wire and of carbon from carbon-steel wire was reduced by from 35 to 45%, compared with conventional metal-spraying methods using only a compressed-air jet. In addition, the corrosion resistance of stainless-steel and aluminium coatings increased in some cases by as much as 400%.

In this connection, it should be noted that the effects of substituting nitrogen for compressed air with conventional gas-heated spraying pistols were reported as long ago as 1936 by Fassbinder and Soulary, who obtained lower hardness values for metals of high melting point sprayed in nitrogen than for the same metals sprayed in air, but practically no differences in the hardness of deposits produced with soft metals under similar conditions. Here again, the Russian report does not go into sufficient detail and, while it is true that the replacement of oxygen by an inert gas is bound to reduce oxidation of the particles in flight, the full effects cannot be realized unless precautions are taken to prevent additional oxygen from the surrounding atmosphere from becoming entrained in the spray stream.

SWITZERLAND

Temperature-Compensated Hair-Springs

By G. KRÜGER. (From *Schweizer Archiv*, Vol. 25, No. 8, August 1959, pp. 299–307, 27 illustrations)

IN cold-worked nickel, as in most metals, Young's modulus E decreases steadily with increasing temperature. However, if cold-worked nickel is annealed, the value of E at first falls rapidly, but then increases with temperature over a certain range, finally reaching the normal value for the cold-worked metal[1] at the Curie point of 258°C. Partial magnetization produces very similar changes[2] in the value of E. The alloys for temperature-compensated hair-springs for watches are so chosen that the Curie point is lowered to about 100°C and are heat-treated in such a way that the residual stresses remaining from cold-working have the effect of leaving the value of E as constant as possible within the desired temperature range; in other words, the thermo-elastic coefficient $\eta = (1/E)\,(dE/dT)$ is nearly zero.

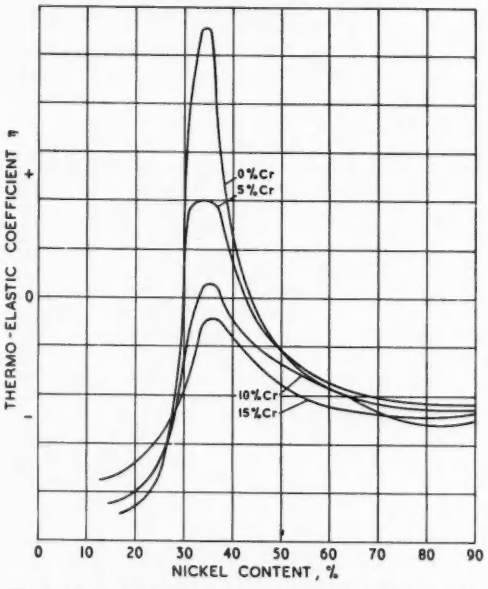


Fig. 1. Effect of nickel content on thermo-elastic coefficient η for Fe-Ni alloys with various additions of chromium.

The ideal requirements for such alloys are (1) temperature compensation over as large a range as possible, (2) low magnetic susceptibility, (3) low damping characteristics, (4) ease of working, and (5) corrosion resistance. However, all these requirements cannot be satisfied simultaneously, since, for example, a large temperature-compensation range is possible only with a high Curie point and hence a high magnetic susceptibility. Moreover, the desired effect should not be too sensitive to small changes in the composition of the alloy concerned; consequently, according to Fig. 1, an Fe-Ni alloy containing 10% Cr would be the most suitable[3], but this again would fix a definite value for the Curie temperature,[2] as shown in Fig. 2. As a result, most of the Fe-Ni alloys used at present contain additions of Mo and Be (or W and Be), of Cr, Ti, and Be, or of Cr, Ti, Be, and C.

FE-NI ALLOYS CONTAINING MO AND BE

In these alloys, which are designated M-alloys, the nickel content is usually 30%. After drawing, the wire is annealed at 1100°C and quenched in water, its Curie point T_c then being —10°C. After a further 45% cold-drawing, the value of T_c rises to +60°C, the thermo-elastic coefficient η being $-1{\cdot}2 \times 10^{11}$ per °C (by comparison, $\eta = -2{\cdot}8 \times 10^{-4}$ per °C for steel). Subsequent tempering at 650°C does not affect the value of η, but reduces the Curie point T_c to 20°C. If, however, the quenched wire is cold-drawn to 99%, the value or T_c rises to 125°C and can be reduced to 85°C by subsequent tempering at 650°C. The thermo-elastic coefficient η is then $-0{\cdot}7 \times 10^{-4}$ per °C, this small value being due mainly to heavy cold-working. The magnetic saturation of these M-alloys is only between 20 and 50 gauss, and their coercive force between 10 and 12 oersteds, so that they may be said to have a particularly low magnetic susceptibility.

The microstructure of the 45% cold-worked alloy shows Ni-Be segregations which, after annealing at 1175°C and subsequent quenching, largely disappear. However, with annealing at 1100°C, the Ni-Be phase is still pronounced. With annealing temperatures below 1000°C, the γ-crystals begin to disintegrate and a new phase appears. At 700°C and below, the Ni-Be phase segregates at boundaries and in slip planes; X-ray examination then shows the solution-hardening features typical of all Be alloys, and hardness increases considerably. Magnetically, the material remains "soft". The microstructure of the 90% cold-worked material is basically the same, as also is that of similar materials containing 40% Ni, although the temperatures of phase and segregation changes are in this case about 100°C lower and the Curie points of the γ-crystals much higher, i.e., 340 to 380°C. The addition of 1% Cr lowers the Curie point by about 30°C and leads to a new characteristic structure when the γ-crystals disintegrate.

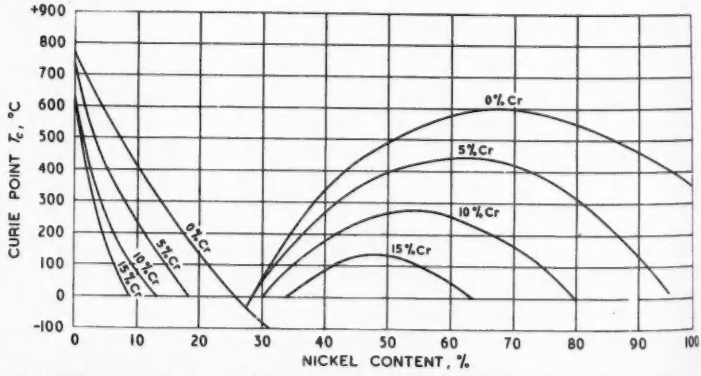


Fig. 2. Effect of nickel content on Curie point T_c for Fe-Ni alloys with various additions of chromium.

Fe-Ni Alloys containing Cr, Ti, Be, and C

These alloys contain from 36 to 40% Ni, 8% Cr, about 1% Ti, up to 1% Be, 1% Mn and Si, and 0·02% C (CT-alloys), or 0·2% C (CTC-alloys). The 45% cold-worked material again shows Ni-Be segregations, which largely disappear on annealing and quenching from 1175°C, but which remain present at lower annealing temperatures. There is no decay of γ-crystals at 1000°C, the first change occurring with annealing at or below 700°C, when Ni-Be segregates at the boundaries and Vickers hardness rises to about 400 kg/mm². The influence of Be content on Vickers hardness, thermo-elastic coefficient η at 20°C, Curie point T_c, and magnetization M_{20} at 20°C is shown in Fig. 3. The best alloys for hair-springs are those containing from 0·8 to 1% Be, because their hardness is high, whilst their values of η and M_{20} are small. The temperature-compensation range extends only up to +40°C, but this is usually admissible for hair-springs.

Magnetic saturation of the CT-alloys is three times higher than in the case of the M-alloys with 30% Ni, but their coercive force is five times less. As a result, although a watch fitted with a CT-alloy spring will change its time-keeping ability in a magnetic field, it will revert to normal after removal from the field. The best alloys in this connection are at present the CTC-alloys, which have a Curie point 10°C higher than that of the CT-alloys and a thermo-elastic coefficient η of only 0·045 × 10^{-4} per °C if the wire is correctly processed. This corresponds to a time deviation in a watch of at most 0·2 sec per day per °C in a temperature range between +4 and +36°C. The magnetization M_{20} of CTC-alloys is 190 gauss, i.e., it is somewhat higher than the value for CT-alloys, owing to the fact that the increased carbon content tends to denude the matrix of solute titanium atoms through the formation of titanium carbides.

Deviations in time-keeping accuracy caused by changes in temperature for watches fitted with various types of springs and adjusted to keep correct time at 20°C are shown in Fig. 4, from which it will be seen that an ordinary steel spring will gain as much as 120 sec per day at 10°C and lose 120 sec at 30°C, i.e., ±12 sec per day per °C. By comparison, an M-alloy containing 30% Ni and Mo will gain about 3 sec per day per °C for temperatures below 20°C, and lose about 3 sec per day per °C for temperatures above 20°C. For a CTC-alloy containing Cr, Ti, and 0·2% C, the watch will gain at temperatures above 20°C and lose at temperatures below 20°C, the amount in each case being roughly only 0·2 sec per day per °C. In the case of a CT-alloy containing Cr and Ti, it will be noted that the watch will lose roughly between 0·3 and 0·5 sec per day per °C, irrespective of whether the temperature is above or below 20°C. It should, however, be mentioned that a small gain is desirable, as it tends to compensate the effects of the thermal expansion of the balance-wheel.

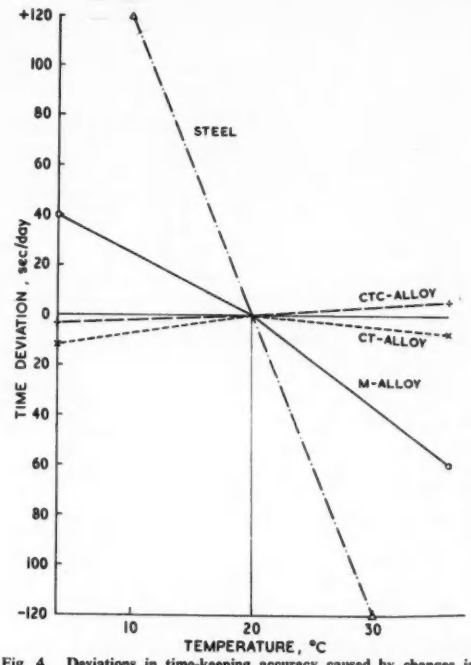


Fig. 4. Deviations in time-keeping accuracy caused by changes in temperature for watches fitted with various types of springs and adjusted to keep correct time at 20°C.

On the other hand, an M-alloy containing 40% Ni can have a very wide temperature-compensation range, depending on the heat treatment employed. With 60% cold-working, the thermo-elastic coefficient η is —2 × 10^{-4} per °C, corresponding to a loss in time-keeping accuracy of 9 sec per day per °C. Subsequent tempering

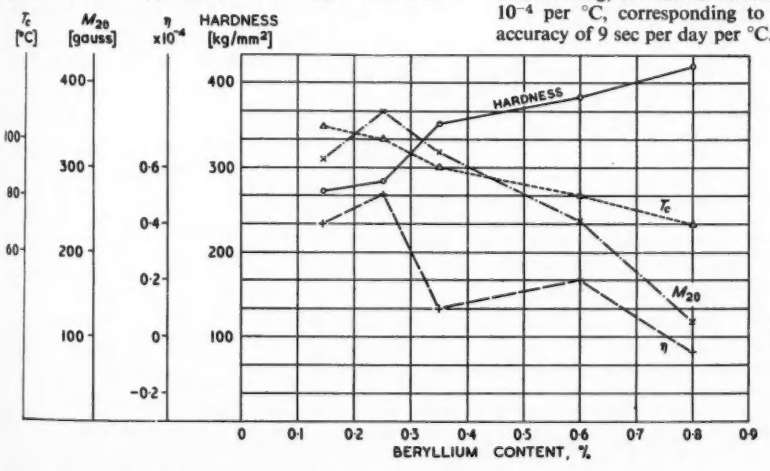


Fig. 3. Effect of beryllium content on various properties of a CT-alloy containing chromium and titanium.

for 10 min at 500°C gives a value of η of about zero, representing a variation in accuracy of from only —0·1 to +0·3 sec per day per °C at temperatures between 10° and 130°C, while tempering for 30 min at 600°C results in a value of η of 2×10^{-4} per °C, i.e., a gain of 9 sec per day per °C. However, despite the wide range of temperature compensation, which may be advantageous for other purposes, this alloy is less suitable for watches, owing to its great magnetic sensitivity, its Curie point being 250°C and its magnetic saturation at ambient temperatures about 500 gauss.

Non-Ferrous Magnetic Alloys

Since the anomaly in the temperature dependence of Young's modulus E is connected with the magnetic state of a metal, any magnetic material showing this anomaly at room temperatures can be used, and more particularly

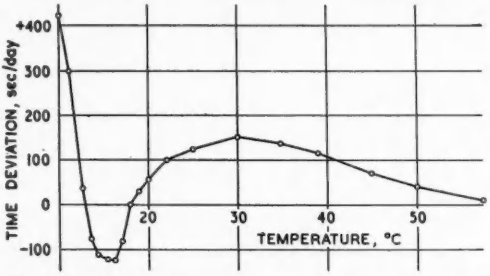


Fig. 5. Deviations in time-keeping accuracy at different temperatures for a hair-spring made of an Ni-Be-Cr alloy, tempered for 15 min at 500°C.

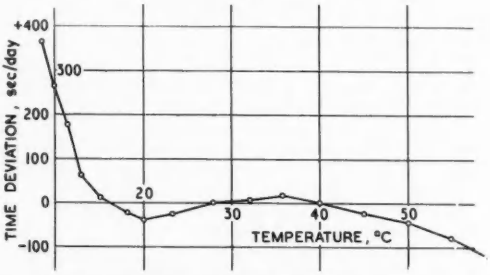


Fig. 6. Deviations in time-keeping accuracy at different temperatures for a hair-spring made of a Cu-Ni-Mn-Zn alloy, tempered for 1 hr at 400°C.

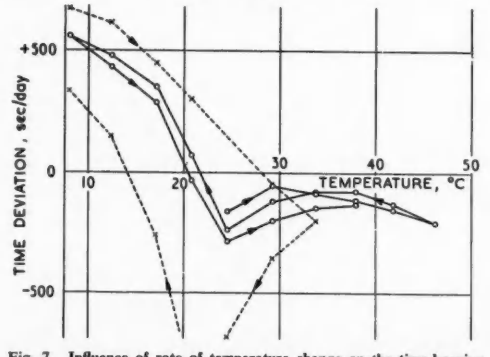


Fig. 7. Influence of rate of temperature change on the time-keeping accuracy a Ni-Be-Cr alloy spring, tempered for 15 min at 500° C, for (solid lines) a rate of 0·2°C/min, and (dotted lines) 1°C/min.

any alloy with a Curie point T_c between, say, 60° and 120°C, so that its magnetic susceptibility remains small. If, moreover, the chosen alloy can be hardened, the thermo-elastic effect can be further influenced by changes in the residual stresses induced by heat treatment. However, as heat treatment also affects magnetic properties, the problem of choosing the right non-ferrous alloy and heat treatment is complicated. Ni-Be-Cr alloys and Cu-Ni-Mn alloys with additions of Zn, Fe, and Al show thermo-elastic properties which are similar to those already discussed. The Ni-Be-Cr group is initially magnetic and hardens by segregation of the Ni-Be phase, while the initially non-magnetic Cu-Ni-Mn group is transformed into the ordered state by tempering above 400°C, then exhibiting magnetic properties and increased hardness.

A nickel alloy containing 2% Be and 2·9% Cr, tempered between 10 and 20 min at 500°C, exhibits a positive thermo-elastic coefficient η of $+0{\cdot}5 \times 10^{-4}$ per °C at temperatures between 20° and 90°C, but becomes negative, approaching a final value of about $-2{\cdot}8 \times 10^{-4}$ per °C with higher tempering temperatures or longer tempering times. The time loss or gain at different temperatures for a hair-spring made of a nickel alloy containing 2% Be and 2·9% Cr, tempered for 15 min at 500°C, is shown in Fig. 5. Some of the Cu-Ni-Mn alloys exhibit a markedly similar behaviour, one example being given in Fig. 6, which refers to an alloy containing 14% Cu, 50% Ni, 16% Mn, and 20% Zn, tempered for 1 hr at 400°C.

These non-ferrous alloys exhibit a certain defect when exposed to rapid temperature changes. Thus, if the temperature is first increased, then reduced beyond the initial temperature, and finally raised again to the initial temperature, all at a rate of 0·2°C/min (solid lines in Fig. 7), the changes in the natural frequency of a spring made of such an alloy follow more or less the same path, irrespective of whether the spring is being heated or cooled at this rate. On the other hand, if the rate of temperature change is 1°C/min (dotted lines in Fig. 7), the frequency, after first decreasing with increasing temperature, continues to decrease even when the temperature is reduced; it starts to increase again only after a considerable reduction in temperature and does not return to its initial value when the initial temperature is reached. Only after a sufficiently long interval of from 4 to 6 hr does the initial frequency reappear. Although, in principle, the same effect must be expected to occur in ferrous alloys, it can be shown to be of a smaller order of magnitude, the frequency change after a similar rapid temperature cycle being only a few seconds per day, with a time of recovery of from 5 to 10 min.

Non-Magnetic Materials

Anomalies in the temperature dependence of Young's modulus E have also been found in beta-brass[4,5,6], glass[7], and Rochelle-salt crystals[8]. These anomalies always occur at temperatures near a point of functional (or homomorphous) transformation without phase change, e.g., the transformation from the ferromagnetic to the paramagnetic state, as used in compensated springs, or transformations from the antiferromagnetic to the paramagnetic state, from the ferroelectric to the non-ferroelectric state, from the ordered to the disordered state, and from the brittle to the plastic state in glass. Certain plastics, e.g., polystyrene, also show such changes. In Pyrex glass, the low-temperature silicate lattice changes at about 500°C, and above this temper-

(*Concluded on page 466*)

Corrosion Protection of Steel and Cast Iron by Oxidation in Superheated Steam

By P. Széki. (From *Acta Technica Academiae Scientiarum Hungaricae*, Vol. 25, Nos. 3–4, 1959, pp. 371–375, 2 illustrations)

As a means of providing protection against corrosion, small cast-iron and steel parts are often oxidized in superheated steam, the oxide layer formed on the surface consisting either of pure magnetite (Fe_3O_4) or of magnetite and wüstite (FeO), depending on the temperature used. However, it would appear that technical literature does not provide information on the protective qualities of the oxide layer, and for this reason the investigation described in this article was considered desirable.

The degree of protection afforded by the oxide layer depends on its thickness and on its adherence. It is true that porosity may also exercise some influence on corrosion protection but, according to the present investigation, there is no need to take it into account in the particular instance considered. Layer thickness depends on the temperature and duration of superheated-steam treatment, and Table I shows the thickness of layers formed on the surface of a steel containing 0·1% C and 0·23% Si and of cast iron containing 3·28% C and 1·74% Si after 1 hr of superheated-steam treatment at different temperatures.

Table I: Thickness of Layers on Steel and Cast Iron

Steam-Treatment Temperature [°C]	Layer Thickness [microns] on Steel	Cast Iron
500	2·45	3·21
550	5·14	6·79
600	10·36	13·47
650	20·20	26·01
700	—	37·25
750	—	72·60

The thickness of the layer is limited by its adhesion to the base material, adhesion being most pronounced in the case of porous parts produced by powder metallurgy. On such parts, even the thick layer formed at a temperature of 800°C adheres perfectly.

A series of experiments was carried out to investigate the protective value of the oxide layer formed on steam-treated steel and cast-iron specimens. For this purpose, specimens were tested by various methods, one of which comprised alternate immersion in a 3% solution of sodium chloride. The basic feature of this method, which considerably accelerates the rate of corrosion and can therefore be classed as a very rapid test method, is to immerse the specimens in the 3% NaCl solution and then to allow the solution on the surface to dry out in air. The immersion period is 7 hr, and the drying period 17 hr, so that the complete cycle has a duration of 24 hr. In practice, the specimens were individually immersed in vessels containing about 150 millilitres of the solution at room temperature and, during the drying period, were suspended above the solution in which they had been immersed. The total testing time was 12 days, i.e., 12 cycles. For purposes of comparison, similar immersion tests were carried out on non-oxidized specimens with pure metallic surfaces. On these specimens, signs of corrosion became immediately apparent, the entire surface becoming corroded after 3 days.

Usually, corrosion tests are evaluated by noting increases in the weight of the specimens concerned or by their losses in weight after removal of the products of corrosion. However, with the alternate immersion test, weight increases cannot be determined, as the major portion of the corrosion products are transferred to the NaCl solution in the form of $Fe(OH)_3$. Also, it was not considered practical to measure weight losses, as all those solvents capable of removing the products of corrosion from the surface would also attack the oxide layer itself.

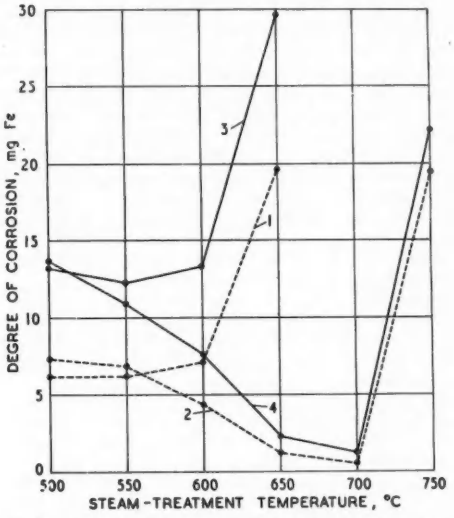


Fig. 1. Degree of corrosion as a function of steam-treatment temperature.
(1) Steel, 7 days. (2) Cast iron, 7 days.
(3) Steel, 12 days. (4) Cast iron, 12 days.

As a result, it was considered that, since the major portion of the corrosion products was transferred to the NaCl solution, informative data could be obtained by determining the iron content of the solution by chemical analysis. During the 12 days duration of the tests, the

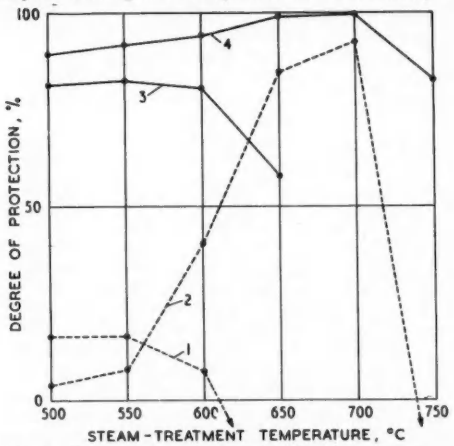


Fig. 2. Degree of protection as a function of steam-treatment temperature.
(1) Steel, 7 days. (2) Cast iron, 7 days.
(3) Steel, 12 days. (4) Cast iron, 12 days.

iron content of the solution was determined twice, the first time being after the 7th day, when the rust adhering to the surface was washed and removed with a brush into the solution, which was then analysed. The test was then continued with a fresh solution and the second determination of its iron content was made in a similar way after the 12th day. It should be noted that, although the iron content of the solution does not give accurate results, it nevertheless furnishes useful data in connection with the degree of corrosion.

The degree of protection was calculated as

$$\text{Degree of Protection} = \frac{100(Fe_{NT} - Fe_T)}{Fe_{NT}} \quad [\%]$$

where Fe_{NT} is the iron content of a non-treated specimen and Fe_T the iron content of a treated specimen. On the basis of the results obtained, Fig. 1 shows the degree of corrosion as a function of superheated-steam treatment temperature, while Fig. 2 shows the degree of protection afforded by the oxide layer at various steam temperatures.

In the case of steel specimens treated at 650°C and cast-iron specimens treated at 750°C, it will be noted from Fig. 1 that the degree of corrosion, as determined from analysis of the iron content in the NaCl solution, is extremely high. This is due to the fact that, with these temperatures, the oxide layer was removed from the surface after only one day of testing in each case, so that the amount of iron in the solution is not only derived from the oxide layer but also from rust produced during testing. As a result, no protective action can be expected from an oxide layer produced at these temperatures.

As shown in Fig. 2, the alternate immersion test on a basis of 12 days duration appears to indicate that the degree of protection afforded by the oxide layer produced by superheated steam is highest, in the case of steel, when the treatment temperature is 600°C or lower, but falls off sharply beyond this temperature. In the case of cast iron, the degree of protection afforded by treatment between 500 and 600°C is also very good, but actually increases with higher temperatures, reaching a maximum at 700°C, beyond which the adherence of the oxide layer is inadequate.

U. S. A.

The Elimination of Chatter in Machine Tools

By M. Sadowy. (From *The Tool Engineer*, Vol. 43, No. 4, October 1959, pp. 99–103, 6 illustrations)

Chatter is often encountered in machine-tool operation and its elimination or prevention is essential if product quality and prolonged tool life are to be preserved. Although it is true that chatter can sometimes be eliminated by changing processing conditions or by switching operations to a sturdier machine, such methods, though effective, do not resolve the basic problem, which is concerned with the fact that studies reveal that chatter can be eliminated to a great extent by redesign of machine tools.

In this article, chatter designates self-excited vibrations in metal-cutting machines, these vibrations appearing to have a characteristic that is approximately constant in a given case. The excited amplitudes are usually very high, i.e., from 100 to 1000 times greater than the average, and a typical build-up of amplitudes can be observed in most cases. Chatter vibrations occur in dynamically unstable systems, so that they can be considered as a stability problem in machine design—a problem sometimes difficult to solve in practice.

Despite various attempts to clarify and classify conditions governing chatter, the theory of chatter is still incomplete. The reason lies not only in the complexity of the chatter problem, but also in the difficulties associated with establishing and comprehending meaningful characteristics and their relation to machine tools in operation. These difficulties are primarily due to limitations in measuring techniques and available instruments. For example, it is difficult to measure the angular and linear vibrations in rotating transmission parts.

Until recently, most investigations into chatter have been concentrated on the influences of cutting conditions. It appears, however, that machine-tool design is no less important. The influence of torsional vibrations in rotating transmission parts still seems to be disregarded. Some investigators are inclined to assume that there are no such influences, or that they can be neglected in comparison with the vibrations of the machine-tool structure.

Various observations in shop practice, e.g., gear noise during chatter and occasional visibly large angular amplitudes of rotating transmission parts, indicate that such parts contribute to chatter. This is also supported by theoretical considerations of the usually very low dynamic stiffness of transmission drives and of the cutting forces, the directions of which are mostly disadvantageous.

Vibratory Systems

A machine tool can be considered as a vibratory system, usually having a complex dynamic behaviour. Relative motion between the cutting tool and the workpiece during chatter results not only from deformations of the cutting tool and workpiece, but also from deformation of the entire machine. Usually, these deformations are most prominent when the machine tool vibrates with one of its natural frequencies, which happens with either resonant forced vibrations or free vibrations. The deformation of the machine at a given instant of maximum amplitudes determines the mode of vibration—the natural mode of vibration in the case of a free vibration. There is a close correlation between natural modes of vibration and natural frequencies.

The modes of vibration, the corresponding natural frequencies, and the damping effective at the particular modes of vibration determine the dynamic behaviour of the machine. These values can be included under the term of dynamic stiffness, or dynamic rigidity. One of the objectives in testing machine tools is to determine these values.

Static and Dynamic Stability

A simple way of determining the stability of a mechanical system is to observe the motion of the system after having displaced its mass from the position of equilibrium. Examples of statically stable and unstable systems are shown in Fig. 1. The system is statically stable if the displacement originates positive spring forces

tending to restore the equilibrium position, e.g., if the deflection initiates a restoring force due to gravity (Fig. 1a). In the unstable system (Fig. 1b), gravity increases the original deflection, i.e., an unstable system has a negative restoring force which supports the displacement. In a system which is stable for small deflections (Fig. 1c), the system becomes unstable for large deflections, the stability boundary condition being $(a + b)\, mg = ka^2$.

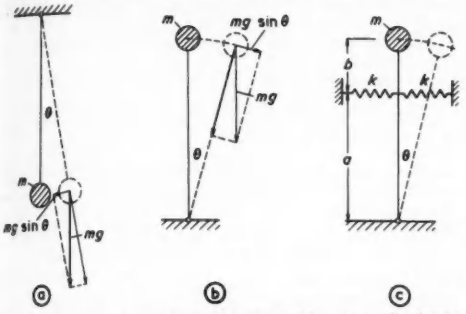


Fig. 1. **Examples of statically stable and unstable systems, showing (a) a stable system, (b) an unstable system, and (c) a system which is stable for small deflections.**

The criterion of static stability or instability is, respectively, the decreasing or increasing static displacement of the disturbed system. The system is dynamically stable if its masses, originally displaced and then released, oscillate with decaying amplitudes towards the state of equilibrium, whereas a dynamically unstable system oscillates with growing amplitudes and thus deviates more and more from the state of equilibrium. In both cases, the systems vibrate at their natural frequencies, and the observed vibratory motion is a free motion. In dynamically stable systems damping is positive, while in dynamically unstable systems the effective damping is negative. The amplitudes of dynamically unstable systems would reach infinite values if they were not limited by non-linearities in the system.

Systems can be stable at small disturbing amplitudes and become unstable at large disturbing amplitudes, or vice versa. Different cases of dynamic stability or instability, depending on the magnitude x_o of the original disturbance, are illustrated in Fig. 2, in which Fig. 2a shows stability at small disturbing amplitudes, Fig. 2b instability at large disturbing amplitudes, and Fig. 2c instability at small disturbing amplitudes.

Stability of Machine Tools

Although a machine tool may be statically and dynamically stable in itself, it may become unstable through the action of forces originating in operation, such as frictional and cutting forces. The machine structure becomes statically unstable, for example, when the cutting forces initiate cutting-tool deflections that have a component in the direction of increasing feed or depth of cut. Because of this, the cutting forces are increased, causing more deflection of the cutting tool, and there is an unstabilizing feedback between the cutting force and the displacement of the cutting edge. Dynamic instability of machine tools can have two main causes, i.e., (1) the negative characteristic of friction developed between the moving parts of the machine tool, and (2) the cutting forces.

Instability in sliding can be observed when the friction characteristic between sliding parts becomes negative. Normally, continuous sliding then changes to a vibratory interrupted motion, generally known as "stick-slip". All sliding parts with relatively low velocity have a tendency towards these disturbances, especially when the moving masses are large and the stiffness of the drive and the internal damping in the system are low. Some reciprocating tables in grinding machines, carriages in heavy-duty lathes, automatically controlled parts, and precision positioning devices are typical examples of these systems.

Stick-slip disturbances can be approximated by a vibration of a simple system with a negative damping characteristic. These disturbances can be eliminated by changing the friction between the moving parts (a difficult problem in many instances) by reducing the masses of the moving members, and by increasing both the stiffness of the drive and the damping in the system. In the latter cases, special measurements are usually necessary to determine the vibrating parts of the machine and to examine the dynamic characteristics of the system, such as the spring constant, masses, and damping.

Instability in cutting is caused by the interaction between the cutting forces and the vibrations of the machine-tool components. From the theoretical point of view, various particular mechanisms of such interaction are possible. When disturbed, the machine starts to vibrate with its particular natural frequencies and with the corresponding modes of vibration. Usually, these modes of vibration also include a relative motion between the workpiece and the cutting tool. If one or more modes become unstable, the amplitude of the motion changes cutting conditions, increasing or decreasing the depth of cut, feed, or cutting speed. When these values are changing, the originally quasi-constant cutting force becomes

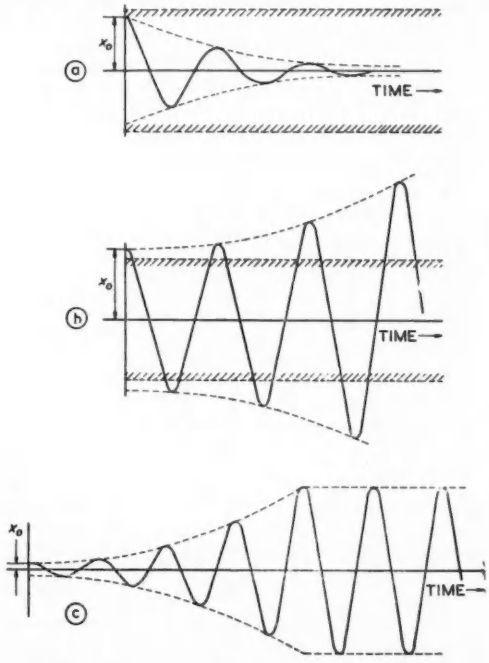


Fig. 2. **Different cases of dynamic stability or instability, showing (a) stability at small disturbing amplitudes, (b) instability at large disturbing amplitudes, and (c) instability at small disturbing amplitudes.**

alternating. It then can increase the vibratory amplitudes of the machine and also the relative amplitude between the cutting tool and the workpiece, which, in turn, builds up the magnitude of the cutting force. The machine itself thus contributes to the progressive increase in chatter.

There is an unstabilizing feedback action between the cutting forces and the machine. The cutting forces can be considered as being controlled by the vibration of the machine, and vice versa.

Experimental Investigations

Chatter experiments were carried out on various machine tools, including a lathe, a horizontal knee-type milling machine, and a radial boring machine. The investigations consisted of measurements of machine-tool deformation under working chatter conditions and measurements of machine-tool deformations under vibratory testing conditions, with the machine tool excited by a vibrator. Recording of the motion of the cutting tool and of the workpiece during chatter was accomplished with a high-speed camera. These camera studies revealed that, on an average, the workpiece stands still for about 35% of each cycle of the chatter motion, and at the same time the cutting speed is approximately zero. During the remaining 65% of each chatter period, there is an acceleration and a deceleration of the workpiece. The latter can be accelerated to such a high angular velocity that the corresponding value of the actual cutting speed greatly exceeds the nominal cutting speed.

In the case of the lathe, the chatter mode can be referred to as a mode in which horizontal bending predominates. The same mode of vibration, excited as a resonant mode, shows not only bending of the lathe bed, but also deformations in the tailstock and in the mounting of the workpiece. With a natural frequency of the mode of 108 cps and a chatter frequency of 143 cps, there seems to be a relatively large difference in frequencies of the chatter and resonant mode. This difference can be explained by the coupling action between the vibrations of the machine bed and the transmission system. Consequently, the chatter involves vibrations of the structure and of the transmission drive.

In the chatter mode of vibration of the milling machine, a tuning-fork motion of the column and over-arm was observed. A relative motion in the slides between the knee and column was also measured. Horizontal bending of the over-arm, twisting of the column, and relative motion between the column and knee were also noted. The chatter frequency was 110 cps.

Qualitatively, similar deformation in a milling machine has been excited at a resonant frequency of 90 cps. In the same way as in the lathe investigated, the milling machine also exhibited a difference between the corresponding chatter and resonant frequencies.

The chatter mode and the resonant mode of vibration in the radial drill were similar, the chatter amplitudes being approximately 20 times larger than the corresponding resonant amplitudes. The mode of vibration can again be referred to as a tuning-fork mode. In the deformation of the machine structure, bending of the column predominates. The frequency of chatter was 37% higher than the corresponding resonant frequency (15·6 and 12 cps respectively).

Unsolved Problems

Two problems appear to be of major importance relative to disturbing chatter vibrations, i.e., determining chatter origin and preventing chatter. At present, the theory of chatter origin is still incomplete, the main difficulties lying in the application of the general knowledge to a particular case. This situation is due primarily to the complexity of the chatter problem caused by the variety of and variation in the parameters involved. These variables can be appreciated by considering the following points:—

(1) Different working conditions of the machine tool with respect to the cutting forces.
(2) Variations in the structural features of machine tools.
(3) Variations in the dynamic behaviour of machine tools of different design.
(4) The influence of mounting of the workpiece and cutting tool.

There are many factors which should be considered, and the only practical approach to the problem lies in its simplification. This, however, presupposes that the importance of the particular parameters in a specific case is known well enough and that the decision to neglect particular parameters is justified. This should be proved not just by mathematics, but by the applicability of the results obtained under simplifying assumptions.

Knowledge of the importance of different parameters, again, would be obtainable only through concurrent theoretical and experimental investigations, not only of chatter itself, but also of associated problems such as the dynamic rigidity of the machine-tool structure, the dynamics of the cutting process, etc.

Prevention of Chatter

Problems, quite different from each other, involve either eliminating chatter in a given case of disturbance or creating a chatter-free machine tool. The first problem is usually an emergency case, in which the machine tool is in use or cannot pass performance tests. Here also, two main cases of instability are possible, one being more or less disadvantageous working conditions for the machine tool, which would operate satisfactorily under normal conditions. The other possibility is that the particular machine is exceptionally unstable if other machine tools of the same type perform satisfactorily. In both cases, an immediate remedy is necessary. Frequently, the only remedy available is that of changing the cutting conditions or placing the job on a more rigid machine.

Building a chatter-free machine is of greater importance than preventing chatter vibrations in a given range of machine operations or increasing the range of operations. Procedure for eliminating chatter could include the following:—

(1) Measuring the chatter modes of vibration.
(2) Exciting these modes under test conditions by using a vibration exciter.
(3) Changing the machine-tool stiffness for the particular mode of vibration, by using vibration absorbers or dampers, or by changing the machine-tool suspension in the case of a particular chatter disturbance, and even by changing the design of the machine-tool structure.

The advantage of such an approach can be seen from the fact that it joins the chatter problem to machine design. Chatter should therefore be considered at the first stage of design, with the primary intention being to prevent chatter rather than to cure it. Furthermore, this kind of approach underlines the importance of machine-tool design for good dynamic performance.

Future Prospects for the Improvement of Magnetic Materials

By F. Pawlek. (From *E.T.Z.*, Vol. 80, No. 17, September 1, 1959, pp. 561–565, 3 illustrations)

The utilization of magnetic materials is intimately related to the generation of electric current, which is constantly increasing, so that it appears appropriate, as well as useful, to consider the degree to which advances in these materials can be expected. In this connection, the question arises as to whether, in addition to the basic ferromagnetic elements (iron, nickel, and cobalt), or alloys containing chromium and manganese, which produce ferromagnetism, it is reasonable to expect the advent of other ferromagnetic elements. It would appear from Heisenberg's theory that, insofar as the rare earths are concerned, such a possibility cannot be ruled out. Thus, some time ago, ferromagnetism was observed in gadolinium at a Curie point of 16°C, and more recently in europium at a Curie point of —183°C and in holmium at a Curie point of —253°C.

Because the production of rare-earth elements in the pure state is very difficult, complete clarification of their magnetic behaviour will probably take some time and, in view of the very low Curie points found up till now, it is hardly reasonable to assume that technically interesting properties in this direction will come to light. Also, the theory of ferromagnetic alloys still appears to require elaboration as, only recently, it was discovered that there is ferromagnetism in the cubic-crystallizing intermetallic compound $ZrZn_2$ at a temperature below —238°C.

The theory of ferrimagnetism is likewise not yet sufficiently comprehensive to permit prediction of magnetic phenomena in compounds of an oxidic or metallic nature with any degree of certainty. In the case of metallic materials, the exchange of forces between adjacent metal atoms gives rise to ferromagnetism, whereas this close proximity is absent in oxidic materials, where the metal ions are always separated by oxygen ions. It must therefore be assumed that there is a " super-exchange " which, in addition to the direct exchange forces, contributes to magnetism. As no firm opinions about this assumption are as yet held, the theory of ferrimagnetism, while it enables an interpretation of observed phenomena to be made, does not make it possible to predict the properties of specific oxide groups.

The influence of microscopic structure on magnetic effects was first recognized about 35 years ago, and today the exploration of submicroscopic and atomic influences is being investigated. First and foremost, a thorough investigation is required into physical lattice defects, such as vacancies and dislocations, and their interchange with foreign atoms, together with their bearing on magnetic phenomena. A start has already been made in this direction. As in other specialized fields of solid-state physics, there is, here too, a growing demand for high-purity materials, as it is only from these that unexpected results can be hoped for. Consequently, extremely pure metals and compounds and perfect crystalline structures will be essential to further progress in research, and this, in turn, raises the difficult metallurgical problem of making available ultra-pure materials in the required quantities.

Permanent Magnets

A permanent magnet should provide the highest possible energy product $(BH)_{max}$, and also, in some cases, a very high coercivity, in order to ensure that it is not affected by strong extraneous magnetic fields. Theoretically, the energy product can be increased by increasing either the remanence B_r or the coercivity H, but it has also been pointed out that increasing the value of H above the value of B_r is, in effect, of no noticeable consequence. In addition, by making the hysteresis loop approximate more closely to a rectangle, a further possibility of improvement can be obtained, and this can be achieved during the manufacturing process by directional magnetic effects.

Comparative figures of merit in terms of the maximum energy product $(BH)_{max}$ for various permanent-magnet materials are plotted against remanence B_r in Fig. 1. In addition, the theoretical limit corresponding to $(BH)_{max} = (B_r/2)^2$ is plotted, and with certain materials this limit has already been reached, while for a number of others an improvement can be expected when their coercivity has been increased.

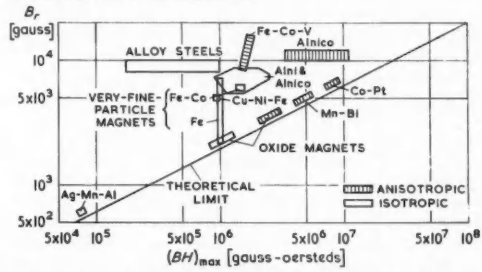


Fig. 1. Figure of merit in terms of maximum energy product $(BH)_{max}$ related to remanence B_r for various permanent-magnet materials.

In the case of the Alnico-alloy magnets, the limit of possible improvement in remanence has now been reached, and very careful refining techniques have given figures of merit as high as 11×10^6 gauss-oersteds. It should be noted, however, that a figure of merit of about 70×10^6 gauss-oersteds is theoretically possible with these materials, and improved smelting techniques, e.g., zone-refining and levitation-melting, may eventually enable this limit to be reached.

With regard to very-fine-particle magnets, utilization of the effects of an admixture of cobalt on saturation has enabled an improvement in the figure of merit to be obtained. At present, magnetic insulation of individual particles is causing considerable difficulties, and the use of lead or synthetic resins as binders has limited the figure of merit, although theory predicts a value of about 50×10^6 gauss-oersteds. Intensive investigations into the surface tension of binders and the wettability of iron and iron alloys are likely to give results which will eventually be closer to the theoretical maximum. Furthermore, with suitable selection of the alloy constituents, it is possible to expect development of a permanent magnet which not only resists ageing, but which is also unaffected by temperature. Such a development would represent a considerable advance in certain fields of instrumentation.

Insofar as the tetragonally crystallizing compound Co-Pt is concerned, an improvement in the value of 9×10^6 gauss-oersteds achieved to date can hardly be expected. However, in the case of the hexagonally crystallizing intermetallic compound Mn-Bi, the value obtained of about $5{\cdot}3 \times 10^6$ gauss-oersteds as a figure

of merit is appreciably below the calculated theoretical value, which is of the order of 15×10^6 gauss-oersteds. However, it is doubtful whether this material will establish itself in practice, as, quite apart from the difficult supply situation for bismuth, there is also a strong tendency for magnets made of this material to corrode, while their coercivity is strongly affected by temperature.

Another group of materials which, like the Co-Pt and Mn-Bi compounds, owe their good permanent-magnet qualities to a substantial crystal anisotropy are oxide magnets of the type $BaO.6Fe_2O_3$. By compressing the powder in the magnetic field, figures of merit up to $3{\cdot}8 \times 10^6$ gauss-oersteds have already been obtained. Screen-grading the powder according to its most advantageous grain size, which is, in turn, based on the optimum compacting density of the powder, together with optimum orientation in the magnetic field during compression, should lead to a figure of merit of about $5{\cdot}4 \times 10^6$ gauss-oersteds. At present, however, the problem of separating the powder has not been solved technically. It is true that there is a prospect of increasing the saturation and hence the remanence by means of suitable oxide combinations, but the theory of ferrimagnetism is not yet sufficiently advanced to indicate the best way to proceed in this respect.

Non-Permanent Magnetic Materials

The question of improved transformer laminations is obviously of great importance, inasmuch as, in terms of quantity, these constitute by far the great majority of magnetic materials used. Transformer-iron losses in Germany alone are estimated to constitute more than the equivalent of £8,000,000 of the total cost of electricity per year, so that a reduction of only a few per cent in such losses would be of economical significance. In this connection, the introduction of cold-rolled grain-oriented sheet about 25 years ago has helped to reduce transformer losses, so much so that losses with this material are less than half those incurred with hot-rolled sheet, which normally has no preferred grain orientation. It is therefore not surprising that, in Germany at any rate, the electrical industry is already satisfying more than 80% of its demands for transformer laminations with grain-oriented material, the possibility of meeting this demand on a 100% basis now being merely a question of the supply situation.

The outlook for further developments in hot-rolled transformer sheet is not particularly encouraging. It is true that annealing of hot-rolled sheet under extreme conditions of high vacuum and temperature (1300°C) results in purification of this material, bringing about a drop in the loss factor L at 10 kilogauss down to $L_{10} = 0{\cdot}55$ W/kg, or $L_{15} = 1{\cdot}5$ W/kg, as compared with the normal L_{10}-value of about 0·85 W/kg and the L_{15}-value of about 2 W/kg. However, even the most carefully controlled production process, followed by high-vacuum annealing, is not likely to result in loss factors even approximately equal to those at present obtained with cold-rolled grain-oriented materials, i.e., $L_{10} = 0{\cdot}45$ W/kg, and $L_{15} = 0{\cdot}95$ W/kg. Even in the case of the so-called grain-oriented hot-rolled sheet, which is first hot-rolled and then cold-rolled without annealing, the optimum loss factor at 15 kilogauss is $L_{15} = 1{\cdot}35$ W/kg, and it is not expected that technical improvements will better this value.

It has long been known that Fe-Si alloys containing 6·5% Si are amenable to heat treatment in a magnetic field, and a rough approximation suggests that loss factors of $L_{10} = 0{\cdot}20$ W/kg and $L_{15} = 0{\cdot}45$ W/kg should be obtainable. However, materials with such a high silicon content are not easily hot-worked and are virtually impossible to cold-work. Admittedly, some work has been carried out in connection with rolling sheet with a high silicon content, but practical data have not as yet been forthcoming, so that the workability limit may still be considered to lie in the region of only 4·5% Si content. In short, it may be said that the chances of improving hot-rolled sheet to a point where they are comparable with likely improvements in cold-rolled sheet appear to be remote.

In the case of cold-rolled grain-oriented sheet, it seems that there are certain limits imposed on possible improvement. At the moment, total losses and hysteresis losses can be established by direct measurement, but eddy-current losses are estimated by means of an empirical formula. On this basis, hysteresis losses amount to about 22% and eddy-current losses to about 33% of the total losses, leaving about 45% for residual losses. Residual losses of this magnitude seem most unlikely in the case of very pure grain-oriented materials. On the other hand, justified doubts have lately been raised regarding the validity of the empirical formula for eddy-current losses, and various new approaches have been attempted. Indeed, studies now tend to indicate that the eddy-current losses in grain-oriented sheet may well be twice as high as those given by the empirical formula, though the theory is not as yet sufficiently established to provide actual numerical values. However, it would appear that a reduction in the loss factor of cold-rolled sheet to an L_{10}-value below 0·4 W/kg or an L_{15}-value below 0·9 W/kg is not feasible.

Owing to the embrittlement which would result, it is not possible to reduce eddy-current losses by increasing silicon content and hence increasing specific electrical resistance. Also, it is impossible at present to state what measures must be taken to bring about improved orientation, combined with a finer crystal structure, in order to reduce eddy-current losses still further. It should, however, be noted that an improvement in grain-oriented sheet may possibly be achieved by perfection of texture, and there are already several promising studies available which suggest that a technical solution to this aspect of the problem may be realized in the next few years. In this connection, measurements made on small experimental transformers have shown that, for high induction values, e.g., 17 kilogauss, the losses incurred when using a cube-textured core material amount to only 60% of those arising when normal cold-rolled sheet is used, although magnetic measurements on samples of sheet are not indicative of any change in the losses, because the preferred orientation is always most pronounced in the direction of rolling. In fact, the actual losses in these transformers are from 25 to 50% higher than those obtained by magnetic measurements.

The first task of the designer must be to find methods of obviating the additional losses attributable to transformer-core construction and assembly. In large transformers, any improvements obtainable by the use of cube-textured materials would probably be less pronounced, as magnetically unfavourable orientation can even now be avoided in grain-oriented sheet by more careful design. In any case, production techniques for large transformers already include all necessary measures which tend to eliminate unfavourable magnetic orientation, so that the introduction of cube-textured sheet

(*Concluded on page 458*)

The Torque-Speed Characteristic and Magnetic Noise of Squirrel-Cage Motors

By T. TORDA. (From *The Journal of The Institution of Engineers, Australia*, Vol. 31, No. 7-8, July-August, 1959, pp. 191-193)

ALTHOUGH single and double squirrel-cage motors are very simple and extremely reliable, they suffer from the disadvantage that they can develop torque-speed characteristics with troublesome large dips, causing so-called "crawling", and that they can produce considerable magnetic noise. These torque dips, as well as magnetic noise, originate from the slot harmonics, although there are several other causes which can contribute to the development of these dips and of noise during starting and running periods.

It is well known that these troublesome features can be reduced by the expedient of skewing the slots or by "chording" the stator coils. Skewing the slots has the disadvantage that it may produce additional losses and/or reduce the torque and power factor. The best method is to eliminate the first cause of trouble, i.e., the interaction between the stator- and rotor-slot harmonics by proper combination of the stator- and rotor-slot numbers and of the pitch of the stator coil. In this paper, slot combinations are discussed for windings with a full coil-pitch, i.e., the coil-pitch is equal to the pole-pitch. Chording will be the subject of a separate paper.

INTERACTION BETWEEN STATOR- AND ROTOR-SLOT HARMONICS FOR FULL COIL-PITCH

Many theoretical studies and practical experiments on three-phase squirrel-cage motors have led to a number of well-known conclusions. Thus, bad starting performance and the development of troublesome magnetic noise is, in the first instance, due to the interaction between the first-order slot harmonics of the magneto-motive-force waves, while the crawling tendency is highest when the first-order harmonics of the stator slots, as well as those of the rotor slots, belong to the same order as the backward-rotating harmonics. It is also known that the interaction of the stator- and rotor-slot harmonics is more pronounced for a squirrel cage of low ohmic resistance than for a squirrel cage of a higher ohmic resistance. Furthermore, magnetic noise, caused by the interaction of the stator- and rotor-slot harmonics, is characterized by $N_1 - N_2$, where N_1 is the number of stator slots and N_2 the number of rotor slots. It is common practice to make $N_2 = N_1 + 4p$, where p is the number of pole pairs, but, as indicated later, this is not the best procedure in every case.

Insofar as a good torque-speed characteristic for a squirrel-cage motor is concerned, the corresponding satisfactory slot combinations can be determined by means of an empirical rule. For the special case in which the coil-pitch of the stator winding is equal to the pole-pitch, this empirical rule has as its theoretical basis that the grade of the slot combination depends on the difference between the orders of the first stator- and rotor-slot harmonics. Thus, if $(N_1 - p)/p$ is the first-order stator-slot harmonic and $(N_2 - p)/p$ is the first-order rotor-slot harmonic,

$$\frac{N_2 - p}{p} = \frac{N_1 - p}{p} + (1 \pm G) = \frac{N_1}{p} \pm G \quad .. \quad (1)$$

where G is a numerical factor characteristic of the grade of the slot combination, and has a value ranging from zero to $2q_1$, where q_1 is the number of stator slots per pole per phase.

The various grades of slot combinations correspond to different values of G in terms of an integer g which includes zero, as follows:—

First grade:— $G = 6g + 2,3,4 = 2q_1$ and/or q_1.
Second grade:— $G = 6g + 2,3,4 + 2q_1$ and/or q_1.
Third grade:— $G = 6g + 1$.
Fourth grade:— $G = 6g$.
Fifth grade:— $G = 6g - 1$.
Sixth grade:— $G > 2q_1$.
Seventh grade: G is an improper fraction.

The first-grade slot combination fulfils all requirements of a good squirrel-cage motor, i.e., smoothness of the torque-speed curve, silence during starting and running periods, and the greatest possible immunity against dissymmetries. In the case of the first-grade slot combinations, there is no need to apply skewing of the slots.

The second-grade slot combinations give satisfactory performance when skewing is applied, but cannot be relied upon when the squirrel cage is of cast aluminium.

The third, fourth, and fifth grades are not reliable when the coil-pitch is equal to the pole-pitch, but can become applicable with proper chording of the stator coil.

The sixth-grade slot combinations are not practicable, because they are liable to produce more or less troublesome torque dips.

The seventh-grade slot combinations are useless, because they produce excessive magnetic noise.

As already stated, magnetic noise is caused by the interaction of the stator-slot and rotor-slot harmonics and is characterized by the difference between the numbers of rotor and stator slots. Thus, from eq. (1),

$$N_2 - N_1 = p(\pm G + 1) \quad .. \quad .. \quad (2)$$

Extensive tests indicate that conditions are favourable when the difference between the numbers of rotor and stator slots is more than the number of pole pairs p, and that the lowest magnetic sound level occurs when $G = 2q_1$ and/or q_1, i.e., the same condition which gives a first-grade slot combination with regard to the torque-speed characteristic. Excessive magnetic noise occurs when G is a fraction and less than $2q_1$, in which case the noise can be akin to that of a siren.

TEST DATA OF AN EXPERIMENTAL SQUIRREL-CAGE MOTOR

It is well known that the interference caused by mechanical and aerodynamic noise with magnetic noise is less for small motors than with larger motors; consequently, the test data obtained with a small motor are specially suitable for investigating the effect of the slot combination on magnetic noise. In this connection, a systematic investigation was described by Stiel* in 1919 into the torque-speed and magnetic-noise characteristics of a 1-hp, 4-pole, 3-phase squirrel-cage motor with a concentric stator winding in 24 slots, using various rotors with different numbers of slots, i.e., 18, 19, 20, 22, 25, 27, 28, 29, 41, and 42. The slots were not skewed and were fitted with copper bars.

* W. STIEL: "Experimental Investigation of the Torque Features of Squirrel-Cage Motors"; *V.D.I.*, No. 212, 1919.

It is interesting to note that the results of this investigation confirm the observations made above with regard to the various grades of slot combinations. Thus, for instance, the satisfactory performance of this motor noted by Stiel with 18 and 22 non-skewed rotor slots is only to be expected, as these correspond to first-grade slot combinations. According to eq. (1), with G negative, $N_2 = 18$ corresponds to $G = 4 = 2q_1$, while $N_2 = 22$ corresponds to $G = 2 = q_1$. It should also be noted that, if Stiel had included tests with numbers of rotor slots up to the maximum permissible, corresponding to $G = 2q_1$, then, with G positive, two other satisfactory first-grade rotor-slot numbers could have been found, i.e., 30 with $G = q_1$, and 34 with $G = 2q_1$. These combinations are often used in standard designs.

With a rotor of 20 slots, the slot combination is of the second grade, and this does not produce desirable starting characteristics with unskewed slots; the torque-speed curve would, however, have been improved by skewing the slots.

With 28 rotor slots, a third-grade slot combination is obtained, and this is impracticable, owing to a crawling tendency. A similar tendency is noted in the case of 42 rotor slots and 41 rotor slots, these belonging respectively to sixth-grade and seventh-grade combinations.

In the case of 19, 25, 27, and 29 rotor slots, these belong to the seventh-grade slot combination and are useless because they produce troublesome dips in the torque-speed curve and excessive magnetic noise during the starting period (when G is a negative fraction), and a high magnetic noise during the running period (when G is a positive fraction). With regard to 29 rotor slots, it is of special interest to note that its combination in this particular 4-pole motor (i.e., with $p = 2$) and 24 stator slots is, as already stated, a bad one, belonging to the seventh grade. If, however, $p = 1$, a first-grade slot combination results, and, in fact, such a 2-pole motor, with 24 stator slots and 29 rotor slots, has a smooth torque-speed curve and silent operation during both starting and running periods.

Practical Examples of Bad Slot Combinations

As a matter of interest, details are given of three practical examples of bad slot combinations and the methods used to remedy the defects noted.

(1) A 15-hp, 4-pole, 3-phase squirrel-cage motor had a concentric coil winding in 36 stator slots and a cast-aluminium squirrel cage in 60 rotor slots. It was found that this particular motor did not accelerate to its normal speed even under no-load conditions, though the magnetic sound level was low.

For the full-coil-pitch, the slot combination belongs to the sixth grade. The first-order stator-slot harmonic, as well as the first-order rotor-slot harmonic, are backward-rotating harmonics. The skewing of cast-aluminium bars is seldom fully effective, and therefore there was only one remedy, i.e., the application of a new rotor with 44 slots (first-grade slot combination), which eliminated crawling.

(2) A 10-hp, 4-pole, 3-phase double squirrel-cage motor, supplied with and mounted on a machine tool, had a concentric coil winding in 36 stator slots and cast-aluminium bars in 48 rotor slots. The motor failed to run up to normal speed.

There were two possibilities of improving the torque-speed characteristic—either to provide a new rotor with 44 slots or to rewind the stator with a double-layer winding, the coil-pitch of which is shortened by one slot pitch, thus applying a chording of 88·8%. The original winding with full coil-pitch had a fifth-grade slot combination.

(3) A 10-hp, 6-pole 3-phase squirrel-cage motor had a concentric coil winding in 54 stator slots and copper bars in 44 skewed rotor slots. The motor, located in the basement of a five-storey building, produced a troublesome noise, which reached even the top-floor offices. Cork placed underneath the baseplate and a groove around the baseplate did not reduce substantially the noise level. The slot combination is of the seventh grade and there was only one remedy, i.e., the substitution of another rotor. A new rotor with 66 rotor slots, corresponding to a first-grade slot combination, eliminated the noise.

Conclusions

The conclusions derived from this paper can be summarized as follows:—

All general-purpose squirrel-cage 3-phase motors with a stator winding of full coil-pitch can be designed to have a smooth torque-speed curve and silent starting and running operation by the application of first-grade and second-grade slot combinations. The rule to be used for the determination of the first-grade slot combinations determines the permissible maximum and the practicable minimum values of the rotor-slot numbers relating to a stator winding of full coil-pitch. In this connection, it may be said that, with regard to the torque-speed characteristic, the maximum permissible number of rotor slots is equal to the number corresponding to $G = +2q_1$ in eq. (1). With respect to magnetic noise, the difference between the number of rotor and stator slots should not be less than the number of pole pairs p, but should rather be more. It should also be noted that a first-grade slot combination does not require the skewing of slots, whereas skewing is required in second-grade slot combinations.

Slot combinations of the third, fourth, and fifth grades are unfavourable in connection with a stator winding of full coil-pitch but, with proper chording of the coil-pitch, several slot numbers can be made practicable.

Future Prospects for the Improvement of Magnetic Materials

(*Concluded from page 456*)

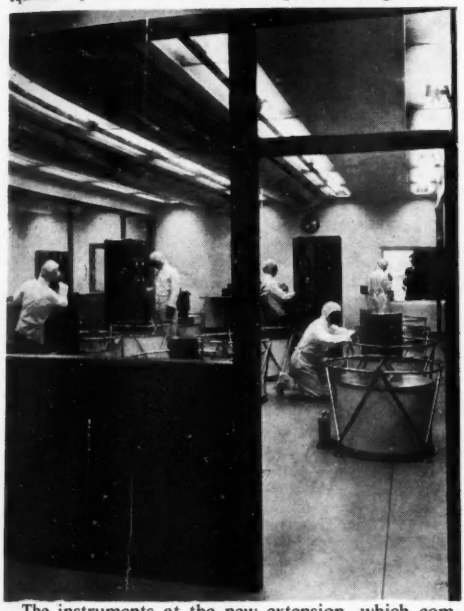
probably does not appear to be of particular promise in this instance. On the other hand, the use of such sheet with a double preferred orientation should make improvements possible in the case of medium-sized and small transformers, and might also be of interest in the construction of very large electric motors and generators. Insofar as iron-nickel alloys and other alloys based on them are concerned, no further developments are likely, as their potentialities have already been fully explored.

As a result of the continuous trend towards higher frequencies in telecommunications techniques, utilization of these materials has fallen off considerably in favour of ferrites, which are free from eddy-current losses, and it would appear that nothing is likely to prove competitive with ferrites, which are finding an ever-increasing application and which have now become an essential material in the entire field of high-frequency engineering. It should, however, be pointed out that the theory of oxidic ferrimagnetic materials is as yet by no means complete, and for this reason it is very difficult to predict future lines of investigation and to assess their possible value.

British Industrial Developments

Production of Inertial-Navigation Instruments

Providing a completely integrated development and manufacturing unit, a recently opened extension to Ferranti's existing laboratory at Crewe Toll, Edinburgh, will be used for the production of a new series of high-precision gyroscopes and accelerometers for inertial-navigation systems, as used in aircraft and missiles. Initially, work will be concentrated on the development and manufacture of these components only, but it is expected that the scope will later be extended to include the development and construction of complete inertial-guidance systems, and of smaller gyroscopes of roughly equivalent performance to those of present design.



The instruments at the new extension, which comprises machine and process shops, assembly and test areas, stores, laboratories, and offices, are based on the fluid-supported system evolved in the U.S.A., in which random errors are generally accepted to be very much smaller than they are in more conventional gyroscopes, in which friction of the gimbal bearings has been the main trouble in achieving high performance. However, in the manufacture of these instruments, it is imperative that no dust particles greater than about 0·5 micron in size and no excess humidity are present in the area where they are assembled. For this reason, the assembly and inspection areas and the store-room for finished parts are temperature-, humidity-, and dust-controlled by means of special plant. In addition, special precautions are being taken to ensure that machined components do not carry any particles of dust, etc. from the machine-shop to the clean areas, protection in this respect being achieved by a system of double air-locks between the machine-shops and a special cleaning room equipped with ultrasonic cleaners. A second double air-lock between the cleaning room and the air-conditioned store-room ensures a minimum transfer of air and dust between the conditioned and the non-conditioned areas.

Strict precautions are also being taken to ensure that dust particles, hair, etc. are not carried into the clean areas by personnel, who will be subjected to a number of "decontaminating" procedures of a type already practised in the U.S.A. Thus, after prior removal of mud from their shoes and then leaving their outdoor clothing in a cloak-room, personnel enter a shoe-changing room which is divided by a low bench on which they sit to remove their outdoor shoes and socks. They then swing their feet over and put on special socks and leather shoes similar to carpet slippers, but which are lint-free. Personnel are then required to go through two steps of undressing and dressing with special lint-free clothing and, at intermediate stages, to be subjected to blasts of high-velocity filtered air, for the removal of loose particles. After donning the final garments, the only exposed parts of the body are the hands and face, as shown in the illustration, which is a view of part of the testing area.

To eliminate vibration, the main air-conditioning plant is of the absorption type, with sufficient capacity to provide cooling water for both the main plant and the plant installed for the changing rooms. The dry-bulb temperature is held at 72° ±1°F at eight points of control in the air-conditioned areas, and good draught-free diffusion of air is obtained by means of special perforated dome-type secondary air diffusers located continuously across the ceiling. Relative humidity is maintained at a maximum of 45%. Filtration of the air is achieved initially by passing it through fibre-glass primary filters and then through two large banks of high-efficiency filters.

Special precautions have been taken to isolate ground-transmitted vibrations from the test area, in which special mountings carrying test equipment for the instruments have been installed. For example, conditions required for one instrument to be produced in the extension stipulate that the mounting carrying the test gear must not be subjected to rotations greater than 1 second of arc or translations with acceleration greater than 0·0001g. In a pit underneath the main floor of the test area are three large reinforced-concrete blocks, the first of these weighing about 60 tons and the other two about 40 tons each. The large block and one of the small blocks are each mounted on four rubber pads and are also fitted with rubber side-buffers which give the necessary isolation of vibration in the vertical and horizontal planes respectively. These two blocks, the tops of which come to within about 12 in. of the underside of the suspended flooring over the pit area, carry a number of aluminium-alloy pillars filled with concrete, each weighing approximately 1 ton, which pass through the flooring. A flexible dust seal is fitted between each pillar and the floor, so that no vibration is transmitted from the floor. The third concrete block carries one test pillar only and is suspended on sixteen helical coil springs, thus giving better isolation from disturbance than on the other two. Damping is achieved by dash-pots filled with silicone oil.

Radioactive-Tracer Technique for Testing Skin Cleanliness

Various methods are employed to prevent the onset of industrial dermatitis, including mechanical handling, protective clothing, the application of barrier creams, and cleansing the skin after each work period. Of these measures, cleansing is one of the most important and, if carried out efficiently, is a valuable safeguard against dermatitis. For this purpose, special skin cleansers have been developed for industrial use, but determination of their actual cleansing or detergent efficiency is by no

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means a simple matter, as conventional visual methods used do not provide accurate comparable or quantitative data. The provision of such data is the purpose of test equipment recently installed by Alexander Duckham & Co. Ltd., of London, W.6, in which skin-cleansing efficiency is measured by means of radioactive tracers. This radioactive technique serves two purposes, i.e., it maintains and improves the detergency standards of the company's existing cleansers, and it provides a research tool for the study of detergency, with a view to developing new cleansers and allied products.

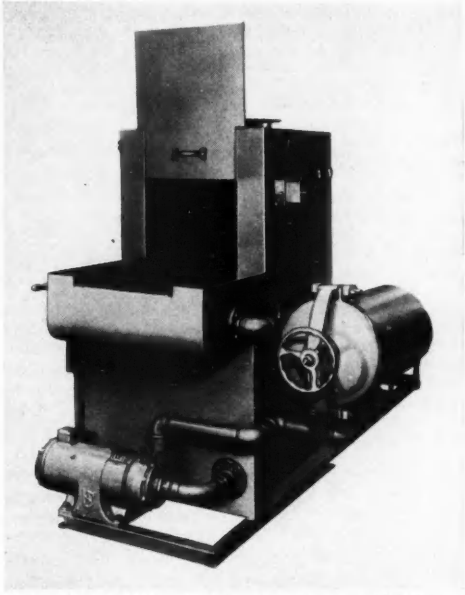
The equipment used consists of a specially constructed "glove-box", in which radioactive isotopes can be handled with safety. Four gloved ports, as shown in the illustration, are fitted to one side of the box, to that two operators can jointly carry out tests. Running water, the flow of which is controlled by a valve outside the box, is laid on to a sink incorporated in the box, and the sink is connected with a screened sump in which washings from the tests remain until such time as the short radioactive life of the tracer elements is exhausted. Each cleansing agent under examination is subjected to a series of five exactly similar tests, each series being preceded by a control test, using a standard soap gel, which provides a datum reading of radioactivity, with which the results of the other five tests can be compared.

For testing, carbon (oil-free lampblack) is labelled with a radioactive tracer which has a marked affinity for carbon and which is mainly a beta-emitter with a half-life of 12 days. The labelled carbon is then mixed with a straight mineral oil having a viscosity of 130 sec Redwood at 140°F, to form a sludge of the desired consistency, the mixture simulating a type of skin contaminant commonly met with in the engineering industry. A measured quantity of the sludge is then applied to the palms of unused chamois-leather gloves, drawn on over the plastic-port gloves and spread evenly over the palms of the gloves. Chamois leather is used for these gloves because the texture of this material is such that, with its pores and flexibility, it simulates, in an amplified way, the human skin. Next, a measured quantity of the cleansing agent under test is applied to the contaminated glove palms and is well rubbed in, after which the gloves are rinsed under running water (London tap-water) to wash off the cleanser, which is now laden with the radioactive sludge. Finally, the palms of the rinsed gloves are placed under a Geiger counter, and their radioactive count is recorded on a scaling unit. The operations of spreading the sludge, rubbing in the cleansing agent, and rinsing are all strictly time-controlled. The flow-rate of the rinsing water is also controlled.

The radioactive count is a measure of the amount of labelled carbon remaining on or ingrained in the glove palms and is therefore a measure of the cleansing or detergency efficiency of the cleansing agent under test. In tabulating test results, the count for the standard soap gel, as already mentioned, is taken as a datum figure. If the count for a cleanser under test is higher than the datum, it is less efficient; if the count is lower, it is a more efficient cleanser than the standard soap gel.

Fine-Filtration System for Metal-Cleaning and Degreasing Machines

Whereas conventional filtration on alkali spray-type metal-cleaning and degreasing machines cope satisfactorily with normal swarf, they are mostly unsuitable for the very fine swarf prevalent in modern machining methods for aluminium, cast iron, and similar metals. As a result, for these very fine swarfs, Dawson Bros. Ltd., of Gomersal, near Leeds, have developed a special cylindrical pressure filter which can be fitted to any of the machines in their wide range of metal-cleaning and degreasing plant. The illustration shows a Dawson "Minor" general-purpose metal-cleaning machine equipped with the new filter.



The basis of the new filtration system, which is neat and compact, is a bag made of heavy-duty, finely-woven nylon fabric, closely fitted over a perforated drum, through which all recirculated alkali solution is pumped before passing through the jetting system. Consequently, even the finest swarf is prevented from returning through the jets. Not only does this avoid the recirculation of swarf onto the parts being cleaned, but it also prevents the jets from becoming clogged up, thus retaining their cleaning efficiency. Furthermore, the jets need cleaning less frequently. A significant benefit of the nylon bag is that it can quickly be removed and a clean bag fitted. The soiled bag is easily cleaned for re-use. The filters, which are fully pressure-tested, are available in three sizes, i.e., 100, 200, and 300 gpm, at pressures up to 20 psi.

Light-Sensitive Cells

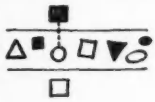
What are light-sensitive cells? They are devices which can sense and measure changes in the level of light or, in some cases, respond to the quality of light falling on them. There are various types of cell and each has its particular field of use. One of the best known is the photo-electric cell.

What can light-sensitive cells do? A change in the amount of light falling on the cell can cause a switch, relay or counter to operate. Alternatively, the direct indication of the light intensity can often allow some other factor to be determined and, if required, controlled. They are reliable and require little maintenance. Careful installation, as with all types of equipment, gives a good reward.

How can they be used? These cells have many applications in industry, for controlling processes, for inspection and measurement, for sorting material and for safety purposes :

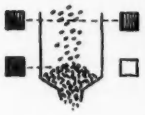
Counting

Where objects on a conveyor belt are too soft or light to operate a direct mechanical counting device, where they are too delicate or freshly painted to sustain physical contact or where the articles vary in size, a light-sensitive cell can be used. This counts the objects by interruption of an appropriately sited beam of light.



Hopper or Tank Level Control

Many forms of feed can be accurately controlled by light cells. One important one is for controlling the input to a hopper of fluid solids such as sand or peas. Here, two horizontal light beams are required : the upper, when interrupted, indicates that the hopper is full and stops the supply; the lower, when it ceases to be interrupted, indicates that the hopper is nearly empty and restarts the flow.



Package Content

The level of powder in packages can be checked with light cells. The cell is so positioned that

when the powder is up to the required level, the light reflected from the surface of the powder is picked up by the cell and causes the carton to be accepted. If not, it is rejected.

Colour Sorting

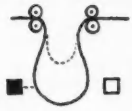
The quality of many articles can be gauged by their colour—seeds and nut kernels, for instance. The objects are fed into a tube by means of a vibrator pan and fall into the beams of three equally spaced light cells which scan them from all sides. If the object is acceptable it falls into a chute carrying it to one conveyor; if its colour is bad it is deflected as a reject.

Guillotine Guard

Light cells for guarding a guillotine or power press should be used only as a supplement to a mechanical guard or where the latter is impracticable. The interruption of a curtain of light by a hand stops the machine instantaneously.

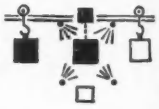
Press Feeding

Where the rate of feed of strip metal must be suited to a varying speed of acceptance by a press, a loop of the strip is allowed to sag between the feed and the press. When the loop reaches a predetermined depth a light beam is interrupted and the slack is taken up.



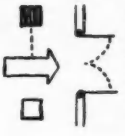
Processing Objects on the Move

Many articles are processed while on a conveyor line. For instance, where articles are to be sprayed while on the conveyor, the paint saved by stopping the gun between articles will make the device worthwhile. The same principle applies in a bakery to the spraying of baking tins with fat.



Automatic Door Opening and Closing

Doors can be caused to open or close by the interruption of a beam of light. This has its uses in such cases as control of doors on a heating oven or for the passage of vehicles in a factory. This is effected by a light beam on the side from which the approach is made (in many cases, both). When the approach beam is interrupted it opens the door which closes again after a given time interval.



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ADDITIONAL ABSTRACTS

Numerous important abstracts which, for lack of space, cannot be published in our main editorial columns are regularly included in condensed form in this section. Subscribers may obtain photostat copies of all original articles at cost.

Influence of Plastic Deformation on the Motion of a Ball Rolling between Two Surfaces.

By K. L. JOHNSON. (From an advance copy of a paper received from *The Institution of Mechanical Engineers, London*, September 1959, 14 pages, 11 illustrations)

WHEN a sphere is used as a rolling element between two surfaces, it is usual to assume that the relative motion of the sphere and the rolling surfaces is not influenced in any significant way by their elastic deformation. To take the rolling bodies as rigid implies " point-contact " between them, whereupon their relative motion is exactly determined by the simple geometry and constraints of the particular arrangement. Of course, contact does not occur at a point. The force, normal to the surfaces, transmitted by the rolling element causes local distortion, albeit elastic, so that contact occurs over a finite area of elliptical shape defined by the Herta theory. Owing to friction, tangential tractions may be transmitted between the rolling surfaces across this area of contact, giving rise to a relative velocity between the two surfaces, which is small compared with the rigid-body motion, usually referred to as creep.

The creep motion results from a small amount of slip between the surfaces, caused by their elastic distortion. It has been shown that slip may and, in fact, does take place over part of the area of contact, even though the two bodies may be rolling together without sliding. It is the purpose of this paper to demonstrate the nature of the creep motion and how the track of a ball rolling between two surfaces is affected by it.

When a ball rolls between two surfaces, a tangential contact force and a relative angular velocity of spin are generally present at each point of contact. Both these actions give rise to tangential frictional tractions transmitted across the contact surface, which are shown to result in a velocity of creep of the ball in a direction perpendicular to the nominal rolling path. The magnitude of the creep velocity depends critically on the magnitudes of the tangential force and the velocity of spin. If these actions are small, there is negligible slip between the contacting surfaces, and the creep motion is predominantly a function of the elastic properties of the materials. At larger spin velocities, slip extends over a greater proportion of the contact area and the creep is influenced by the frictional properties of the surfaces.

The Dependence of Creep Behaviour on the Duration of a Superimposed Fatigue Stress.

By A. H. MELEKA and A. V. EVERSHED. (From a report of *The British Iron and Steel Research Association, London*, September 1959, 14 pages, 8 illustrations)

ALTHOUGH a substantial amount of research work has been conducted in the field of creep and fatigue separately, only few experiments have been made in which the two types of stress are present simultaneously, and then only for the purpose of obtaining engineering data. However, fundamental studies in which creep and fatigue stresses were applied separately to the same specimen have been made by Kennedy, who investigated the effect of fatigue on the recovery of mechanical properties. The effect of a fatigue stress on thermal recovery was studied by removing the creep stress and applying a fatigue stress during the recovery period, and an accelerated recovery index was obtained from the subsequent static creep behaviour.

As described in this paper, specimens were investigated when the creep and fatigue stresses were applied simultaneously, and also when the fatigue stress was subsequently removed. It was found that the superposition of a fatigue stress in a creep experiment results in a sudden increase in the creep rate, which decreases with time, the strain following a law related to $t^{2/3}$, where t is the time. If the fatigue stress is removed, the resulting creep rate is even less than the original static rate, this hardening following the same law.

In this study, a model based on the increased mobility of an oscillating dislocation is proposed to explain the softening due to fatigue, the subsequent hardening being attributed to the effect of vacancies produced by the fatigue stress.

Free-Convection Heat Transfer in the Inclined Open Thermosyphon.

By B. W. MARTIN. (From an advance copy of a paper received from *The Institution of Mechanical Engineers, London*, September 1959, 16 pages, 19 illustrations)

A SURVEY of the literature concerning free convection shows that, although considerable attention has been paid to heat transfer from vertical and horizontal surfaces, both from the theoretical and experimental standpoints, there are very few references to work on inclined surfaces, and in particular to the influence of the angle of inclination on heat transfer. The investigation described in this paper is concerned with the effect of tilting in the particular case of the open thermosyphon, which consists essentially of a heated tube, closed at the lower end and open to a reservoir of convective fluid at the top. Thus, under the influence of gravity, the heated annulus of fluid adjacent to the tube wall moves towards the open end, where it discharges into the reservoir. This is simultaneously replaced by a central core of cooler fluid entering the tube from the reservoir. In this way a circulation is established.

The open thermosyphon has several projected applications, including cooling high-temperature gas-turbine rotor blading. In this application, the thermosyphon takes the form of a blind-ended radial passage within each blade, all such passages communicating with a fluid reservoir in the rotor drum. The acceleration necessary for free convection is effectively created by rotation. The present investigation has, in fact, been largely inspired by this application because of the presence in a rotating thermosyphon of a Coriolis component of acceleration which acts on each fluid particle.

Inclination of the tube sets up a secondary acceleration normal to its principal axis. The pressure gradients which are thereby induced should assist the circulation of fluid from the cold to the hot stream, thus reducing the thickness of the annulus and increasing the area of the core. The increased effectiveness of the system might then be expected to improve the heat-transfer rate. This is found to be true in laminar flow (of the boundary-layer type) except for small tilting angles. The weak secondary pressure gradients which then occur are believed to be responsible for mingling of the fluid particles on the common boundary, and this reduces the heat transfer. The same general trends are apparent even when there is some degree of turbulence in the system.

The static turbulent regime is not of the boundary-layer type, because of the tendency for the cool entering fluid also to become turbulent, but is what is called fully mixed flow, where the two turbulent streams mix, causing reduced circulation and heat transfer. Under these conditions, sufficient tilting of the tube eventually brings

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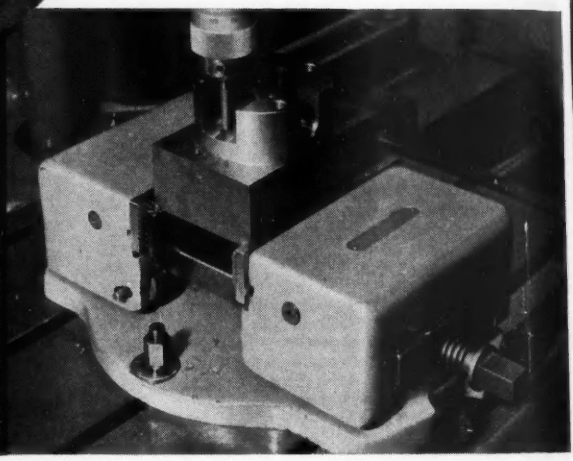
DOWN GRIP



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about the elimination of the mixing effect and a more efficient transfer of fluid particles between the two streams. The greatly increased heat transfer appears to be consistent with a stable turbulent boundary-layer flow régime, which, if attained, would improve the effectiveness of the open thermosyphon as a cooling device for both nuclear reactors and gas-turbine rotor blades.

A Hydrostatic Thrust-Type Shaft Seal for Hydrogen-Cooled Generators.

By W.W. GARDNER, A. LEHRKIND, and W. L. RINGLAND. (From *Power Apparatus and Systems* (*A.I.E.E.*), No. 43, August 1959, pp. 653–659, 9 illustrations)

THE shaft-seals of hydrogen-cooled turbine generators present increasingly difficult design problems as shaft diameters become larger, and higher hydrogen pressures are used. To meet present and future requirements in these respects, a new thrust-type shaft seal has been developed and is being applied on current machines.

In the new seal, hydrostatic rather than hydrodynamic principles are employed to maintain the oil film. Also, centrifugal effects of the rotating oil film are utilized to oppose and greatly reduce oil flow to the hydrogen side of the seal.

The seal is essentially a hydrostatically lubricated thrust bearing in which the thrust load to be supported by the oil film consists of the spring force, the force produced by the hydrogen pressure acting on the end of the seal ring and O-ring, and support-pad friction forces resulting from axial movement of the shaft. This last force may be in either direction. These forces are balanced by the oil-film pressure distribution maintained by the oil-supply system at the face of the seal. Since pressure is fixed by the applied forces, oil flow through the seal is determined by the pressure-volume characteristics of the oil supply. The seal automatically accommodates itself to the required oil-flow and pressure conditions by operating at a corresponding oil-film thickness.

Because the hydrostatically maintained oil-film pressure is only slightly higher than the hydrogen pressure, bearing pressure on the babbitt seal face is very conservative for all foreseeable hydrogen-pressure requirements. Also, the oil-film pressure adjusts itself automatically for changing hydrogen pressure, maintaining just enough pressure for effective sealing. Oil-film thickness is sufficiently large, because of the hydrostatic lubrication, to reduce losses to acceptable values and to provide improved tolerance for dirt in the oil supply, manufacturing variations, and thermal distortion. In spite of the relatively large oil-film thickness, oil flow to the hydrogen atmosphere is very low, reducing hydrogen contamination and allowing the use of a moderate-size hydrogen-detraining tank rather than vacuum oil-treating equipment. The low hydrogen-side oil flow is the result of centrifugal pressures in the rotating oil film opposing the small pressure differential tending to produce hydrogen-side oil flow. Axial motion of the seal, following shaft expansion and contractions, is insured by a hydraulically actuated automatic-thrust device which reinforces the normally adequate spring force, when necessary.

Switching Surges and Insulation Strength.

By B. GANGER and G. HOSEMANN. (From *Brown Boveri Review, Switzerland*, Vol. 46, No. 5, pp. 279–287, 9 illustrations)

IN recent years, increasing interest has been shown in the behaviour of high-voltage equipment exposed to non-atmospheric over-voltages, such as those produced by switching operations in the power system. To facilitate the prediction of the actual insulation strength in all circumstances likely to be experienced in service, investigations have been carried out to determine the electrical strength of a number of typical arrangements in air and in oil, using a wave-form corresponding to a single half-wave with a duration of about 1 millisecond. In this paper the results of these studies are compared with the corresponding breakdown voltage on 1/50 impulse, with the power-frequency voltage, and with a wave-form suggested by other authors.

In oil, with its high impulse factor, the strength, when subjected to a power-frequency voltage for one minute, is always below that measured when the duration is shorter. For a series of arrangements with insulated electrodes, such as are used in the manufacture of transformers (e.g., interturn insulation specimens with an oil-gap, connections, and end-distance models), the strength in the face of switching surges has been observed to drop by as much as from 5 to 20% on the average, compared with the figure obtained with the standard impulse. As the present measurements prove, this cannot be applied without reserve to surface-discharge arrangements or non-insulated electrodes in oil, and is certainly not true of air insulation. In the voltage range examined, i.e., up to a peak value of several hundred kilovolts, the arrangements in which the electrodes are not coated with solid insulation possess greater strength in the face of switching surges than on impulse.

In air, where the difference in the flash-over voltage due to the change to another form of stress is only modest in any case, the result of the build-up of a strong space charge and the resultant deformation of the electrostatic field is that the breakdown value for simulated switching surges is, in most cases, fairly close to the power-frequency voltage, and sometimes even below it. Therefore, especially for air insulation, it is advisable not to count on the strength in the face of switching surges being any higher than the long-time power-frequency voltage.

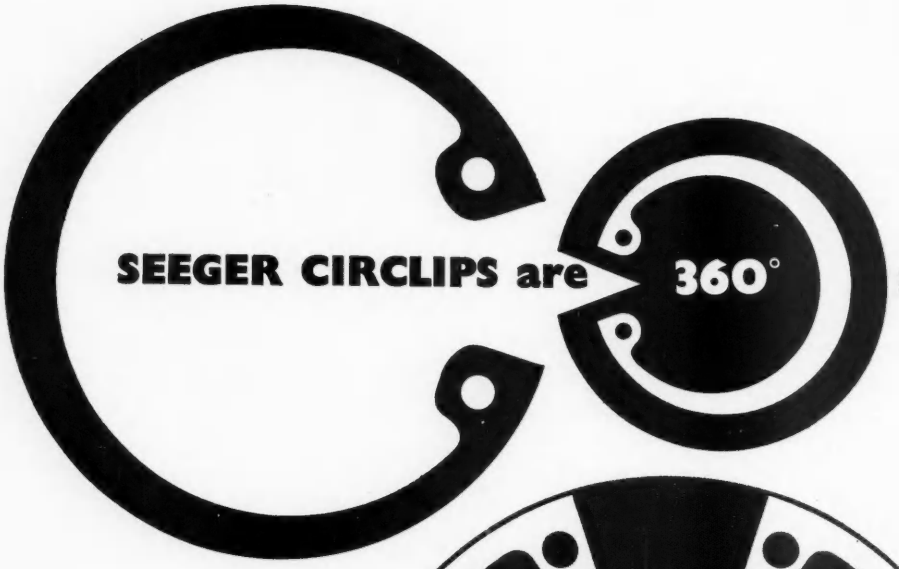
From the measurements obtained so far it is evident that it ought to be possible to determine the true electrical strength of electrical equipment with sufficient accuracy when its behaviour in the face of a high impulse and the one-minute power-frequency voltage is known. The need for special tests on finished equipment with overvoltages similar to those produced by switching operations therefore appears to be unjustified.

Present-Day Feedwater Treatment for High-Pressure Boilers.

By P. HAMER. (From a paper presented at a meeting of *The Institution of Mechanical Engineers, London*, October 21, 1959, 13 pages)

THIS paper is concerned with industrial boilers working at 1000 to 2000 psi, i.e., about 550 to 640°F, generating power and steam for manufacturing processes, and thus having a high make-up of treated water as compared with the closed feedwater systems in power-station boilers, where little steam is lost. In the former case, the size of the water-treatment plant for boiler plants of comparable evaporation, and consequently the capital and chemical costs for treating a particular water, are much greater than for power-station boilers, so that the owners are perhaps rather more concerned to examine all possible methods of treatment. A few figures are given to illustrate this point, and a plea is made that water treatment should be studied carefully at an early stage in any project for new boilers.

The quality of feed and boiler waters now in use, or recommended, is shown in two tables, and it is clear that, above about 1500 psi, the trend is towards "pure" feedwater, though this may not be essential. The paper also discusses the control of steam purity to prevent corrosion and deposits, by elimination of carbon dioxide and oxygen, addition of volatile amines, control of the concentration of salts and silica in the boiler water, and the possibility of steam washing. A short description is given of the circumstances which, it is believed, have caused numerous cases of corrosion in high-pressure boilers, and countermeasures are suggested. These comprise strict de-aeration of the feedwater, addition of alkalis to the boiler feedwater, to prevent corrosion in the pre-boiler equipment and in the boiler, and the avoidance of hot spots or sluggish flow by boiler design and operation.



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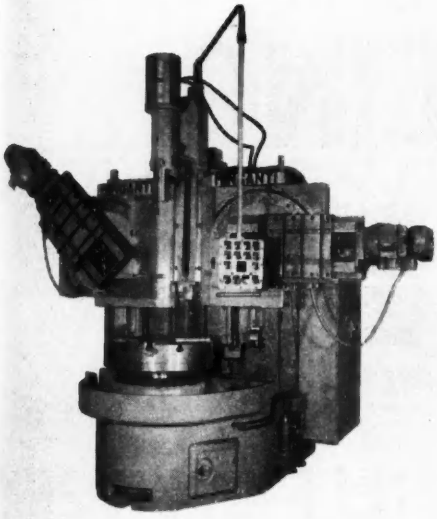
New Materials, Processes, and Equipment

DUAL-CARRIAGE VERTICAL LATHE

Designed to enable a wide variety of boring and turning operations to be carried out automatically, without recourse to punched cards, cams, or templates, the new type TVM.01 vertical lathe shown at the recent European Machine Tool Exhibition in Paris by Giuseppe Minganti & C.-S.P.A., of Bologna, utilizes two distinct tool-carriages, each of which can be set for different operational programmes and which can be moved to any position between vertical and horizontal. As a result, simultaneous operations can be carried out on workpieces from both carriages, while the vertical disposition of the spindle facilitates mounting of large and heavy components.



In operation, one of the tool-carriages approaches the workpiece rapidly with either a vertical or an inclined movement, after which it proceeds at preselected feed rates, stopping at the end of a predetermined work cycle. The other carriage accomplishes similar movements, as required, and, after an adjustable period of dwell, both carriages finally retract from the workpiece, returning to the starting position, stopping the spindle, and automatically setting up the necessary speeds for the next workpiece. Spindle speeds are preselected on a push-button station, and are changed by means of electromagnetic clutches. The programming controls for moving and stopping the carriages are of an electromechanical type.

FLOW-RECORDING CHLORINATOR

A new chlorinator produced by Chlorination Equipment Ltd., of London, W.C.2, incorporates a flow recorder in its construction, thereby saving space, avoiding trailing connections between the units, and resulting in improved efficiency by eliminating the losses which can occur from remote mounting of the recorder. The chlorinator, which is accurate and reliable, is available in two types, i.e., type NMF for manual operation, and type NAF for fully automatic dosing, each type with thirteen different meter sizes, ranging from 0·125 to 40 lb of chlorine per hour with a control range of 10 to 1. A supply of charts, calibrated according to capacity, is provided with each instrument.

The recording unit is installed in the head of the equipment, and readings can be taken at a glance through an amply proportioned glass panel which opens to allow easy access to the unit without interfering with the chlorinator. The recorder operates from the metering differential, which is transmitted to coupled bellows and is obtained by connections across a specially designed valve inserted between the vacuum regulator outlet and the meter inlet. The vertical movement of the bellows-coupling controls the pen-driving mechanism. A continuous recording is provided on a seven-day drum chart which is calibrated in pounds of chlorine per hour and which displays a generous area to facilitate the observation of past readings. The most important components of the chlorinator, such as the injector block, chlorine regulator, valve body, and piping, are made from plastic materials which have been specially developed for their chlorine- and water-resisting properties. Corrosion-resistant alloys are used where necessary.

To enable the operator to alter the capacity of the instrument, the chlorine flow-meter and the control-valve stem and sleeve assembly are, like all the major components, situated in an easily accessible position. Several safety features are incorporated in the basically simple design of this instrument, so that it can be operated by unskilled labour.

MULTI-PURPOSE ANALOGUE COMPUTER

Specially intended to deal with modern scientific problems and incorporating all the automatic aids necessary to ease the handling of many complicated problems, including nuclear kinetics, a large multi-purpose analogue computer of entirely new design is being introduced by Short Brothers & Harland Limited, and includes a considerably extended printed-circuit system and a special patching system which completely eliminates cord clutter. The basic instrument is a 112-amplifier linear computer, but it has been so designed that the specific requirements of individual users can easily be met merely by plugging the specified components into the standard racks. Up to nine special non-linear components can be incorporated, if desired.

The computer consists of seven standard racks, the three control racks being confronted by a double-pedestal desk. The transistorized power units are located below desk level, and the measuring equipment and non-linear components (if any) above desk level. The twin racks on each side of the desk are identical in construction and contain the computing elements, interconnection of the elements being effected by two patch panels set into the desk top. These twin racks are of modular construction, with 56 modules per rack, and each twin unit consists of one rack of amplifiers and one rack of passive elements. Each of the racks containing the passive elements is a double-walled temperature-stabilized oven, the inner enclosure being maintained at a temperature which is held constant to within $\pm 0{\cdot}5°C$, the resulting component accuracy being better than 0·01%. All computing units, including those of the temperature-stabilized elements, are removable from the front for ease of maintenance.

One of the most noteworthy features of the design is the patch panel by which the active and passive outputs and inputs are interconnected. The connections are made by single-pin plugs and single patch cords but, although up to 20,000 different connections are possible and up to 100 cords can be employed per panel, none of the cords cross, and, as the cords are adjustable in length, there are

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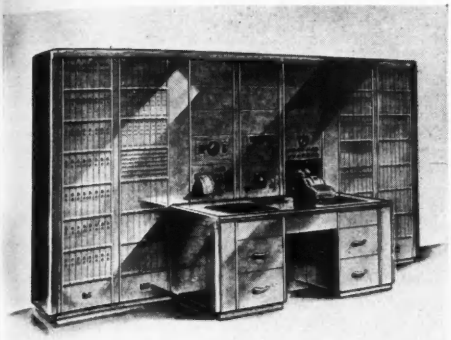


no unsightly loops of cord to obscure the panel, which is fully screened and removable to facilitate the storage of problems.

A new design of selector panel enables any amplifier output to be connected to any of the measurement channels, or any of the servo-set potentiometers to be set up from the control desk by means of selector buttons and setting keys. Thirteen measurement channels are provided which, apart from the mandatory digital voltmeter, can be arranged to suit individual requirements. The digital voltmeter and associated printer displays a four-digit fraction of 100 V and is accurate to 0·01%. What is believed to be the most comprehensive checking system yet devised for any computer ensures a rapid check of all circuits and connections, the sequence being automatically stopped if any errors are detected.

Although the capacity of the computer has been carefully planned to meet the demands of present-day mathematicians, it can be extended, where necessary, by twin-rack units identical with the main racks. The extension units may contain up to 56 active and 56 passive modules, and extension patch panels are provided, these being connected to the main patch panel by 50 bus-bars. The selector panel on the main control desk can handle up to four extension units, but modifications can be made to permit the addition of more than four extension units.

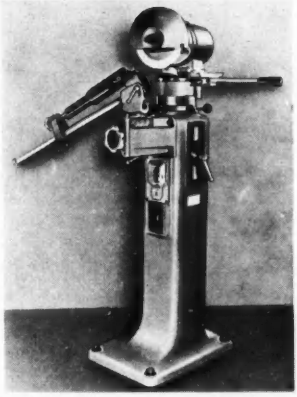
MINIATURE INSULATION-TESTING EQUIPMENT

The latest addition to the range of miniaturized electronic test equipment produced by Nash & Thompson Ltd., of Chessington, Surrey, is their " Nashton " flash-tester, which is designed for insulation testing to B.S. 816-1952 and provides a 50-cps a.c. test voltage, variable from 5000 to 2000 V in sixteen steps of 100 V by means of a rotary switch. The test voltage is derived from the high-voltage secondary of a transformer via a current-limiting circuit and is varied by the 16-step rotary switch, which is connected to the primary winding of the transformer, the maximum short-circuit current being 4 mA.

Measuring only 6 × 6 × 8½ in. and weighing 6 lb, the instrument operates from standard a.c. mains supplies. The applied voltage and the associated leakage current are indicated on a 4½-in. rectangular moving-coil meter, the appropriate meter scale being selected by a two-position switch. The probe can conveniently be clipped in position on one side of the case and, to ensure safety in operation, the probe tip is shielded by a spring-loaded insulating sleeve which is retracted when not required for use.

DRILL-POINT THINNING MACHINE

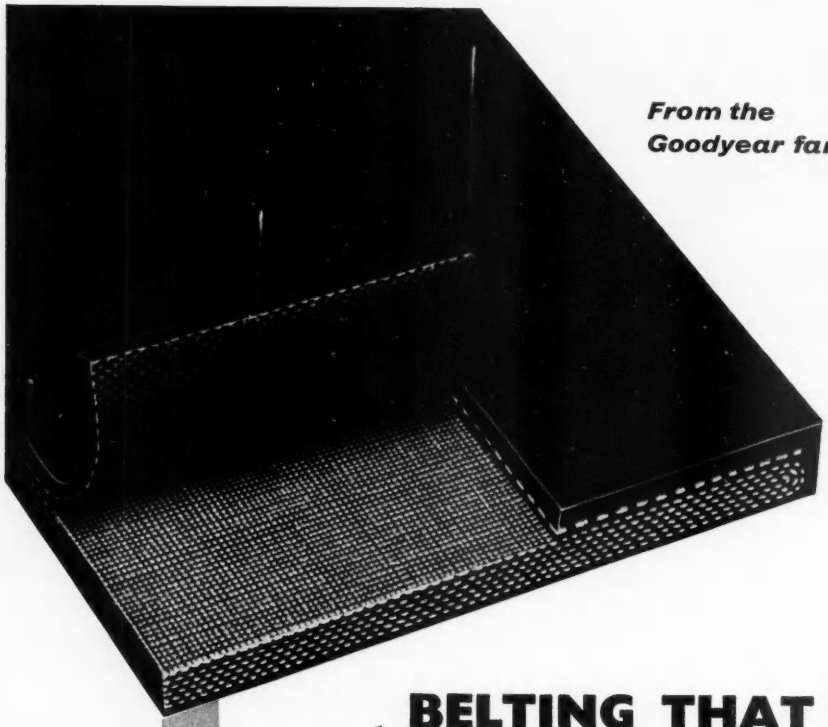
Stated to provide an improved method of point-thinning on twist-drills, the new " Dormer " drill-point thinning machine exhibited by The Sheffield Twist Drill & Steel Co. Limited, of Sheffield, at the recent European Machine Tool Exhibition in Paris, utilizes one size of wheel for all known types of thinning and a rapid and simple method of loading the drill and changing from one diameter to another. Furthermore, it is fully adjustable for various types of point-thinning, no special shaping of the wheel is required, and correct modification of the core is automatically produced.



The drill is stationary during grinding and is supported at the point by a conical rest and located by a Vee-type end-stop, the shank being held by either a male or female tailstock centre. This drill-holding unit is swivel-mounted on a slide, providing universal positioning of the drill. To simplify operation of the machine, all setting positions are clearly marked for each drill diameter. The grinding-wheel assembly is mounted on a pivot, enabling the wheel to be swung manually through the drill flute. The feed is automatic, and each time the wheel is swung through the flute it is ratched-fed by 0·003 in. After one side of the web has been ground to the desired depth, a stop is locked, ensuring that the identical depth of thinning is repeated on the other side. The correct shape of thinning is achieved on drills of all sizes by setting the grinding-wheel axis in relation to the pivot, this setting being provided on a calibrated scale.

INDUCTION COUPLINGS FOR SPEED AND TORQUE CONTROL

Believed to offer a radically new approach to the problem of a.c. motor control, the new TASC induction couplings developed and manufactured by Pye Electric Limited (Lowestoft Division), of Lowestoft, Suffolk, are not only designed for cheap mass production and extreme durability, but are capable of providing precise speed and torque regulation over a wide range with an accuracy of control to within 3%. The full torque value is variable



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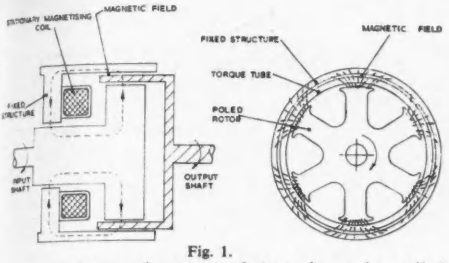


Fig. 1.

over the entire speed range, and the unit can be stalled down without overheating. Furthermore, no maintenance is required, the use of slip-rings or brushes is eliminated, and there is no physical contact between the members, except on the shaft bearings.

Basically, the TASC (Torque and Speed Control) induction coupling consists of independently rotating input and output members, separated by a small air gap and supported by a stationary fixed structure. As shown in Fig. 1, which refers to the smaller versions of the coupling, the input member, which is driven at a constant speed, comprises an input shaft carrying a poled rotor. The rotor is surrounded by a copper or aluminium torque tube, which is mounted on a boss attached to the output shaft, forming the output member. The fixed structure consists of a casing ring surrounding the torque tube at one end and carrying at the other end a stationary magnetizing or exciter coil, with its turns concentric to the axis of the rotor. As the exciter coil is fixed, the need for slip-rings is eliminated. In the larger versions of the coupling, the input member carries the torque tube, and the output member the rotor.

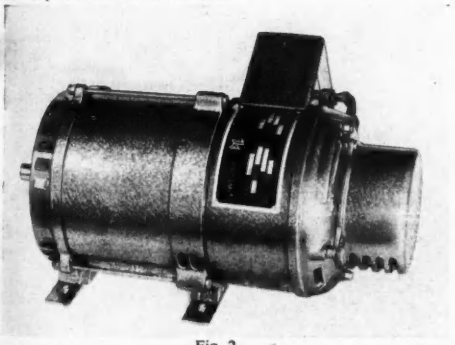


Fig. 2.

When the exciter coil is energized from a d.c. supply, a steady magnetic field is set up, as shown in Fig. 1, the field streaming out from the pole-faces of the rotor to the casing ring and rotating with the poles of the rotor, thereby inducing electrical currents and hence a magnetic field in the torque tube. The two fields interact, producing in the tube a torque which tends to drive it in the same direction as the poled rotor. The magnitude of this induced torque, which is applied to the output shaft of the coupling, is directly proportional to the value of the exciter-coil current and is thus easily controllable. Torque is almost independent of speed, so that the coupling is inherently a variable-torque device.

The exciter-coil current can be varied from a d.c. source by means of a rheostat for providing the required control. Alternatively, use can be made of a variable transformer fed from an a.c. power source, with the transformer output rectified to feed the coil. In both cases, it is possible to calibrate the device in torque units. Another controller, with a more general application from the point of view of remote control by low-power sensing devices, is also available and makes use of a thyratron current regulator, permitting the controlling actuator to be of a low-power type. Speed control with varying loads can be obtained by fitting a tacho-generator to the output shaft, the output of the generator being used to close a simple speed-servo loop.

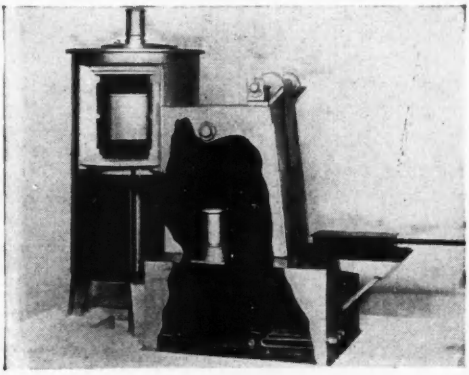
At present, these couplings are available as integrated machines, i.e., complete with drive motor, as shown in Fig. 2, or as couplings alone. The integrated machines are supplied as single-phase $\frac{1}{4}$-hp or $\frac{1}{2}$-hp units, with respective speed ranges of 60 to 1200 rpm and 130 to 2600 rpm, or as three-phase $\frac{1}{2}$-hp or 1-hp units, with respective speed ranges of 65 to 1300 rpm and 130 to 2600 rpm. Individual couplings are available in a range of capacities from 1 to 10 hp, with speed ranges of 65 to 1300 rpm or 130 to 2600 rpm.

VERTICAL CYLINDRICAL CLOSED QUENCH FURNACE

A new vertical cylindrical atmosphere furnace which combines the advantages of pit-type gas carburizers with facilities for closed quenching, hitherto available only in horizontal equipment, is announced by the Electric Resistance Furnace Co. Ltd., of Weybridge, Surrey. Because of its cylindrical shape, the chamber accommodates a larger volume of work in a smaller wall area and operates at greater efficiency than an equivalent horizontal rectangular furnace. An economy in gas or electricity consumption of the order of 15% is effected, while atmosphere consumption is also reduced, owing to the smaller volume of the heating chamber to be purged. The mouth of the heating chamber and bung are designed to form a heat trap.

The vertical cylindrical heating chamber is closed at the top and has provision for the insertion of a charge through the base. The furnace can be electrically heated by special resistance elements or gas-fired with radiant tubes. The charge is shielded from direct radiation by a heat-resisting baffle suspended from the furnace roof or, alternatively, the sides of the charge basket. A powerful fan of large diameter, mounted directly above the charge, draws the atmosphere up through the charge and forces it down over the heating elements, ensuring uniformity of heating and intimate contact of the atmosphere with all surfaces of the charge. The work, normally in a nickel-chrome basket, is moved into the furnace through an outer verticle rising door to enter the purging vestibule, where it stands on one of the two platforms of the quench elevator. At the outer door, a gas curtain automatically prevents ingress of air when the door is open, both the door and the quench elevator being pneumatically operated. After purging, the charge is transferred to the furnace bung, where it is supported on suitable stools which allow free circulation of the atmosphere.

A feature of the furnace is the use of a charge trolley to move the charge horizontally from the outer loading table into the purging vestibule and to and from the fur-



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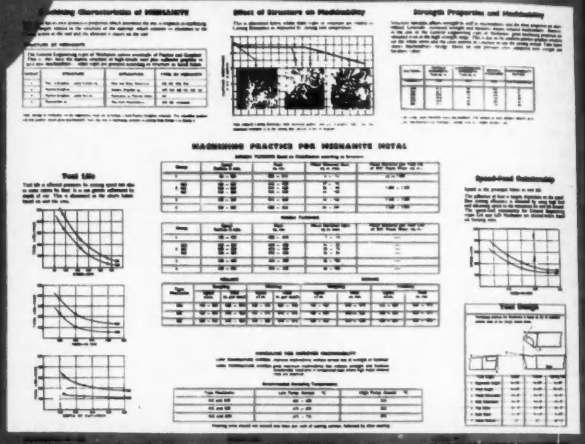

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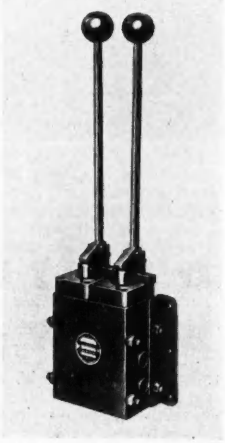
nace bung. The trolley runs on rail tracks and is fitted with wheels which are mounted on ball bearings and carried in an articulated frame to ensure easy movement. Built into the trolley is a raising and lowering mechanism operated from outside the furnace with a removable push rod. The trolley can be moved in and out of the furnace without raising the outer door, a swinging counter-balanced flap attached to the outer door being provided for this purpose. After charging, the trolley is lowered and withdrawn. The use of the trolley obviates the need for hearth rollers and, apart from the fan, no mechanical parts are subjected to furnace temperatures.

The charge is removed from the chamber by lowering the bung and transferring it to the quench elevator by means of the charge trolley. When it has been lowered into the integral quench-tank, the outer furnace door can be raised and a new charge inserted. The purging vestibule and the space beneath the heating chamber are water-cooled. The quench-tank, of adequate capacity, is fitted with oil preheaters, a multi-tube water-cooling system, and a two-speed reversible agitator and baffle arrangement to direct a large volume of oil over the charge being quenched. The agitator, its driving motor, and the cooling system are mounted on a removable top plate for easy access. The furnace can also be supplied with a hot-oil quench-tank for marquenching. For easy maintenance, the roof of the furnace chamber is removable and gives access to the fan and the heating elements or radiant tubes.

SENSITIVE HYDRAULIC CONTROL VALVES

Specifically designed for the hydraulic operation of heavy-duty clutch and brake mechanisms of the type used on cranes and winches or any similar mechanisms requiring constant manual control, the new type-4879 control valves announced by Keelavite Hydraulics Limited, of Allesley, Warwickshire, enable a maximum hydraulic pressure of 1500 psi to be sensed and controlled, although the maximum pull required on the lever of the valve is only 18 lb. These valves can be supplied singly or in multiples of six, though they are usually supplied in pairs for combined clutch and brake operation. If required, they can be adapted for foot operation.



The design of these valves confers the advantage that increased movement of the control gives a corresponding increase in hydraulic pressure, thus providing progressive braking or declutching. Furthermore, the greater is the hydraulic pressure applied to the actuators, the greater is the resistance felt by the operator, who is thus afforded a sense of "feeling" the hydraulic pressure, permitting a far higher degree of control than it is possible to achieve with conventional valves.

PNEUMATIC TYRES WITH REPLACEABLE TREADS

What may well prove to be one of the most outstanding developments in the history of pneumatic tyres is the new BS 3 tyre announced by the Pirelli organization. In this tyre, only the part must subject to wear, i.e., the tread, needs to be replaced, and the tread pattern can be varied to suit prevailing weather conditions and fitted without special tools or equipment.

In essence, the BS 3 tyre may be likened to a tyre around a tyre. Thus, as shown in the illustration, the tyre consists of three peripheral steel-reinforced tread-bands designed to fit onto a casing or carcase. Ridges around the crown of the carcase locate the bands parallel with each other; the bands are slightly smaller in diameter than the casing itself and can easily be mounted in position when the casing is deflated. When the casing is inflated, pressure is exerted, locking the bands firmly in position. The illustration shows the tyre fitted with standard treads, but winter treads are also available. In addition, another patented development makes it possible to insert a series of spikes or studs tipped with tungsten carbide for use when driving on ice.

At this juncture, it may well be asked, in view of the fact that the tread-bands are mounted with the tyre in the deflated condition, what is likely to happen in the event of a burst carcase when driving. In this connection, it

Temperature-Compensated Hair-Springs

(*Concluded from page 450*)

ature the glass is plastic; in fact, its elastic modulus increases from room temperature to about 500°C and then decreases.

A great number of materials thus show desirable properties, but the requirements for hair-springs are so very high that only the Fe-Ni alloys appear to satisfy them, with the exception that they always remain magnetic. Alloys with an order-disorder transformation, e.g., beta-brass, may prove useful in this respect. Moreover, the change in the value of Young's modulus E with temperature depends largely on the crystal orientation in beta-brass, as shown by tests on single crystals[6]. Between 0 and 200°C, the change in the value of E with temperature is negative for the [111] direction, positive for the [100] direction, and roughly zero for the [110] direction. In polycrystalline beta-brass, therefore, a slightly negative thermo-elastic coefficient η can be expected and has, indeed, been found experimentally. If it should prove possible to orientate the structure so that the [100] and [110] directions lie preferentially in the direction of elastic loading, then the thermo-elastic coefficient should be very small or even zero. Tests have established the fundamental correctness of this expectation, even if the very small values that can be expected from the single-crystal tests have not as yet been realized in practice.

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Speed reducers off the peg

Speed reduction problems are most part solved when you call in David Brown. Take the RADICON for example, did you know there are 270 standard models of this popular speed reducer, sizes 2¼ to 28, available for despatch within 24 hours? In the smaller sizes because demand is so great, delivery is a little longer.

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Talk to David Brown about it today — on Huddersfield 3500 or Elgar 6824.

DAVID BROWN

THE DAVID BROWN CORPORATION (SALES) LIMITED

SIZES 2¼ TO 28: RADICON DIVISION · PARK WORKS · HUDDERSFIELD · TELEPHONE 3500.

SIZES 1¼ TO 2¼: LONDON GEAR DIVISION · STONEBRIDGE PARK WORKS · LONDON N.W.10 · TELEPHONE ELG 6824

OA/5788

may be said that the consequences arising from such a condition are hardly likely to be any more serious than those arising from a sudden burst in a conventional tyre. Insofar as relatively slow deflation from a puncture is concerned, the makers state that the tread-bands will not become detached until considerable deflation has occurred and that, even then, the bands will not become jammed under the tyre and cause instability. Furthermore, the partially inflated casing is perfectly capable of travelling safely over some distance without the bands.

If, as the makers claim, the cost of the BS 3 tyre is more or less the same as that of a conventional tyre, the economic advantages of this development, from the point of view of tyre-repair and replacement costs, are indeed remarkable. For example, when the treads are worn out, the cost of their replacement is obviously very considerably less than that of a complete replacement tyre of conventional design and appreciably less than that of a retread. In this connection, it should be noted that the makers claim that, under normal conditions, the life of the casing should outlast that of three sets of tread-bands. Similarly, where a conventional tyre may need replacement or at least extensive repair in the case of a badly cut or damaged portion of a new tread, all that is required in with the BS 3 tyre is replacement of one of the tread-bands—again an obviously far more economical solution. Another point to consider is that, in some cases, cars require two complete sets of tyres, one for normal, and the other for winter, conditions. With the BS 3 tyre, all that is required are two sets of tread-bands with one common carcase, representing a considerable saving, compared with the cost of two complete sets of conventional tyres. Finally, even in the event of a completely ruined carcase, the cost of the casing is still less than that of a complete tyre of conventional design. It should also be noted that most punctures in conventional tyres, irrespective of whether they are tubeless or not, do not normally occur until they have covered more than 75% of their expected mileage, i.e., until the tread begins to wear thin. With the BS 3 tyres, however, tread-bands can be replaced economically by new treads before this inconvenience arises. Moreover, the steel reinforcement in the base of the tread-bands protects the casings from penetration throughout their life.

These new tyres are already in production in Milan by Pirelli, and plans to produce them at the associated factories of their other companies throughout the world, including the Pirelli factory at Burton-on-Trent, are well under way.

Progress in Electron-Beam Welding

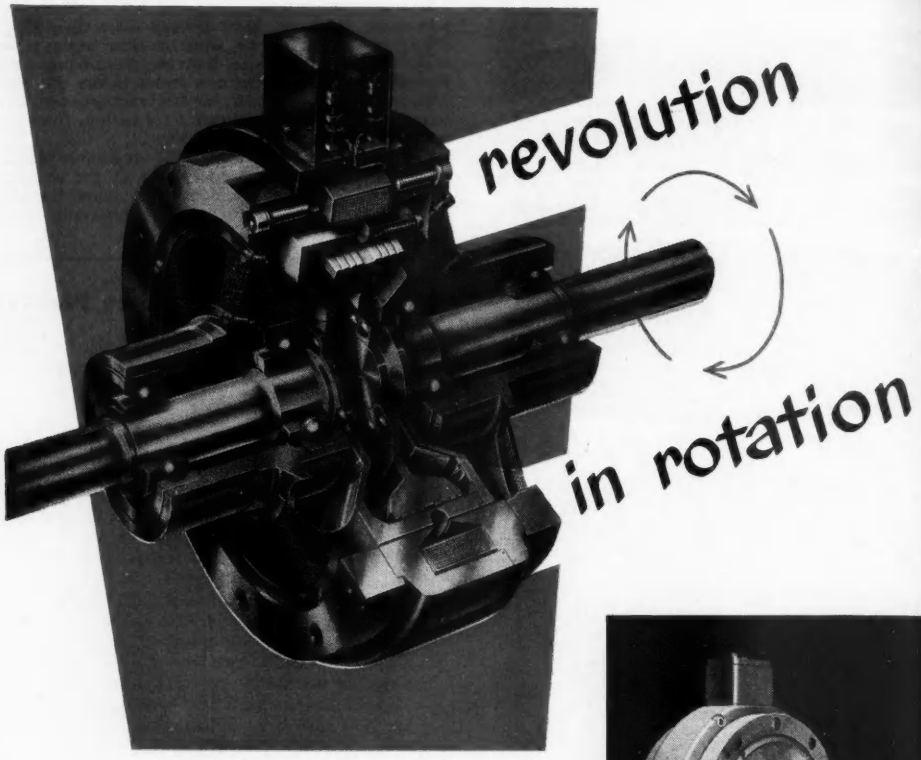
(*Concluded from page 444*)

duction-welding process for both subassemblies and clusters will be developed.

Problems to be Solved

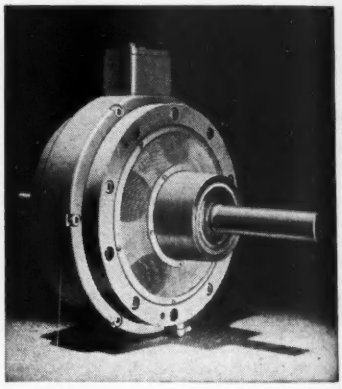
Although satisfactory welds from the aspect of chemical and mechanical properties have been obtained in Zircaloy-2 with the 1-kW laboratory electron-beam welding machine, at least one major problem requires attention in the construction of a production welding machine of the future, i.e., the excessive variability in weld penetration from one weld to the next, owing to difficulties in arriving at and maintaining machine-control settings. This results in an inability to reproduce a specific degree of weld penetration at will. It should be noted that the 1-kW welding machine reported here was a laboratory model made available for developmental welding applications, and it is anticipated that new units will have this difficulty eliminated through the application of suitably modified controls. One possible solution would be the use of stepping switches which would adjust control settings in discrete predetermined and accurately calibrated steps. Although continuously variable adjustment would be lost, positive settings for the controls could in this way be obtained and operator error eliminated. Furthermore, the electronic circuits of the welding machine, although highly developed by German engineers, were not specifically designed for welding applications and will require additional automatic stabilization to obtain the desired degree of constancy necessary for production welding.

A second problem in electron-beam welding of production parts is foreseen in the heat build-up within the workpiece during multi-pass welding on a large assembly. In tungsten-arc welding, the latent heat of fusion is transferred from the work to the surrounding inert-gas atmosphere and thence to the chamber walls, where it is dissipated to the surrounding air. An equilibrium temperature of 160°F inside the chamber (i.e., work and inert-gas atmosphere) is usually reached after 2 hr of welding on large nuclear-reactor assemblies, and a 1-hr cooling period is required after completion of welding before exposure of the part to the air. It has been calculated that a similar assembly welded with an electron beam in a vacuum would reach approximately 800°F and would require 4 hr to cool sufficiently to be exposed to the air. Although it is possible to fill the chamber with an inert gas after completion of welding, this vitiates one of the attractive features of the electron-beam process. No entirely satisfactory solution has been reached, but calorimetric studies have been planned which are expected to reveal the exact nature of this problem and to provide a solution.



SMITHS
Magnetic Particle COUPLING

This is a positive coupling working on a new principle. It is NOT a magnetically operated clutch, and there are no plates to wear.



Driving and driven members are coupled by magnetically activated particles, giving perfectly smooth take-up and accurate control of torque. Eight standard units are made ranging from 1/3 to 200 lb/ft.

SMITHS **S. SMITH & SONS (ENGLAND) LIMITED**

INDUSTRIAL PRODUCTS DEPARTMENT, WITNEY, OXON. Telephone WITNEY 678

AP/85

NEWS OF THE MONTH

PERSONAL

Mr. J. E. Smith has been appointed managing director of the National Gas & Oil Engine Company Limited and a director of Hawker Siddeley Industries Limited.

Mr. J. W. Ashley, B.Sc., has been elected technical director of Atomic Power Constructions Limited.

The Lincoln Electric Co. Ltd. announce that they have appointed **Mr. R. J. Wright,** export sales manager, a director of the company.

Air Chief Marshal Sir John Baker has been elected to the board of Air Trainers Link Limited and has been appointed chairman of the company in succession to **Mr. J. M. Wallace.**

Mr. P. E. Montagnon, O.B.E., B.A., B.Sc., has been appointed manager of the research department of the Lightfoot Refrigeration Company Limited.

B.S.A. Tools Division announce that **Mr. S. A. Roberts, M.I.Mech.E.,** has been appointed managing director of the division.

Mr. K. M. Fox, A.M.I.E.E., has been appointed manager of the industrial machines department (Rugby) of the A.E.I. Motor and Control Gear Division. **Mr. D. N. Delf, M.B.E., A.M.I.E.E.,** has been appointed manager of the industrial electronic apparatus sales department.

Ferranti Limited announce that **Mr. E. Grundy, O.B.E., B.Sc., M.I.Mech.E., M.I.E.E., Mr. J. Prince, M.I.E.E.,** and **Mr. O. M. Robson, M.A., M.I.E.E.,** have been appointed to the board of the company.

Mr. R. N. Davies, works director at Cowley and chairman of the Motor Car Body Divisional Board, has been appointed a local director of the Pressed Steel Company Limited.

At the annual general meeting of the British Standards Institution, **Mr. R. E. Huffam** has been elected president of the institution for a second term of office. **Sir Roger Duncalfe, Sir Herbert Manzoni,** and **Mr. J. Ryan** have been re-elected deputy presidents.

English Steel Corporation, Ltd. announce that **Mr. K. Chatterton, A.M.I.C.E.,** chief engineer, parent company, **Mr. A. M. Simmers, A.C.A.,** secretary and chief accountant, parent company, and **Mr. A. Taylor, A.C.A.,** chief accountant, subsidiary companies, have been appointed special directors of the corporation.

Mr. R. C. McCormick, B.A., M.Sc., has joined Airtech Ltd., as chief electronics engineer.

British Industrial Callender's Construction Co. Ltd. announce that **Mr. C. H. Frankland, M.I.E.E.,** has retired from the board and that **Mr. R. Betley** has been appointed an executive director of the company.

Mr. D. C. H. McLean has been appointed managing director of Lamson Engineering Co. Ltd., in succession to **Mr. R. L. Herring,** who has retired as managing director, but will remain on the board of the company.

British Ropes Limited announce that **Mr. D. Smith** has been appointed general manager of the fibre division, **Mr. E. D. Nicholson** general manager of the wire division, and **Mr. S. Watts** general manager of the wire-rope division of the company. Mr. Watts has also joined the board of directors, while Mr. Nicholson has relinquished his post of secretary and has been succeeded in this position by **Mr. J. R. K. Buckley.**

Wing Commander E. W. Anderson, O.B.E., D.F.C., A.F.C., F.I.N., F.R.Met.S., has been elected president of the Institute of Navigation.

Mr. D. G. Hill had been appointed manager of the air filter department of Air Control Installations Ltd.

Mr. F. H. Beasant, B.Sc., M.I.Mech.E., M.I.E.E., M.I.Loco.E., has been appointed deputy manager of the Traction division of the Brush Electrical Engineering Company, a member of the Hawker Siddeley Group.

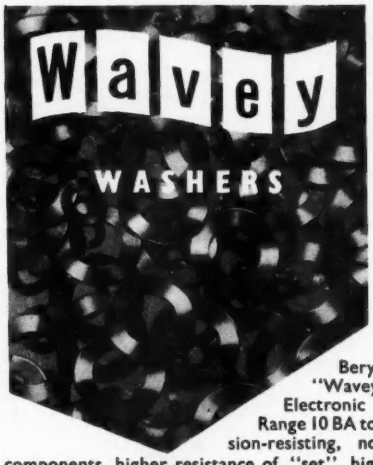
Wickman Limited announce the appointment of **Mr. R. L. Dixon** as director and general manager.

Mr. J. E. Robison, M.I.Mech.E., M.I.Mar.E., chief engineer of Hepworth & Grandage Ltd., has been appointed to the board of directors of the company.

Mr. J. C. Simmonds, M.Sc. (Eng.), Ph.D., M.I.E.E., M.I.Mech.E., managing director of Airmec Ltd., has also been appointed managing director of British Communications Corporation Ltd., and of Radio Television Trust Ltd., the parent company of Airmec Ltd.

Sir W. H. Bailey & Co. Ltd. announce that **Mr. A. Kirkham** has resigned from the board of directors and joined the Foundries Division of David Brown (Industries) Ltd.

Mr. H. F. Macintosh has been appointed manager of the Gear Division of George Angus & Co. Ltd.



Beryllium Copper "Wavey" Washers. For Electronic Components. Range 10 BA to $\frac{5}{8}$" BSF. Corrosion-resisting, non-damaging to components, higher resistance of "set", higher recovery of load, permanent spring action. They are fabricated from Beryllium copper, heat treated to VPN. 350 minimum, Electro Plated to DTD.924, Cadmium plated to DTD.904 and Passivated to DTD.923. Also supplied Silver Plated, or Self Colour or to customer's specification. Samples and price lists on request.

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RESILIENT WORKS, REDDITCH
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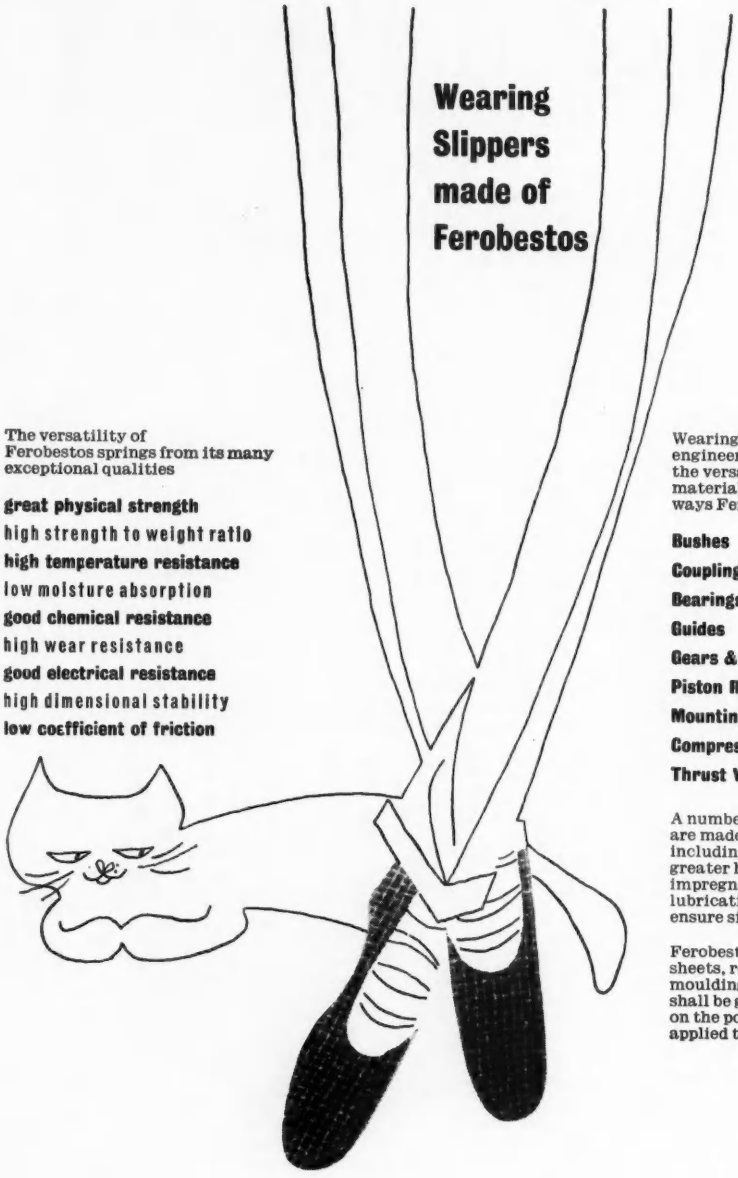
LEAVE IT TO **Lewis** OF REDDITCH
SPRINGS. SPRING CLIPS
PRESSWORK. WIRE FORMS
VOLUTE SPRINGS

Wearing Slippers made of Ferobestos



The versatility of Ferobestos springs from its many exceptional qualities

great physical strength
high strength to weight ratio
high temperature resistance
low moisture absorption
good chemical resistance
high wear resistance
good electrical resistance
high dimensional stability
low coefficient of friction

Wearing slippers is only one of the engineering applications of Ferobestos—the versatile, asbestos-reinforced plastic material. Here are just a few more of the ways Ferobestos can be used:—

Bushes
Coupling Discs
Bearings
Guides
Gears & Rollers
Piston Rings
Mounting Pads
Compressor Blades
Thrust Washers

A number of special grades of Ferobestos are made for particular applications including silicone impregnated for greater heat resistance, and graphite impregnated for more efficient lubrication. Ferobestos gear wheels ensure silence in operation.

Ferobestos can be supplied from stock in sheets, rods, and tubes. Special mouldings can be made to order. We shall be glad to recommend and advise on the possibilities of Ferobestos as applied to any particular industry.

J.W. ROBERTS LTD

Chorley New Road, Horwich, BOLTON, Tel: Horwich 840

Branch Sales Offices: LONDON, GLASGOW, BIRMINGHAM, LEEDS.

A Member of the Turner & Newall Organisation

BUSINESS NOTES

The Power-Gas Corporation Limited has transferred its activities to two wholly owned subsidiaries, i.e. **Ashmore, Benson, Pease & Co. Ltd.,** who will control the Stockton works which manufacture and sell all types of heavy engineering products and will specialize in the design and manufacture of plant and equipment for the iron and steel industry, and **P. G. Engineering Ltd.,** who will undertake design, supply, and erection of plant and equipment for the chemical, petroleum, petrochemical, gas, nuclear-energy, and other industries. The board of Ashmore, Benson, Pease & Co. Ltd. now consists of Mr. W. R. Brown, chairman, Mr. C. E. Wrangham, vice-chairman, Mr. T. K. Hargreaves, managing director, Mr. C. Robson, Mr. D. M. R. Brown, and Mr. R. P. Key. The board of P. G. Engineering Ltd. consists of Mr. W. R. Brown, chairman, Mr. C. E. Wrangham, managing director, Mr. P. M. K. Embling, general manager, Mr. C. Robson, Mr. C. Ingman, and Mr. T. H. Riley.

The Merrick Scale Manufacturing Company, of Passaic, N.J., U.S.A., announce the formation of a British subsidiary, **Merrick Scale Manufacturing Company Ltd.,** with works at Nottingham, for the manufacture and sale of continuous conveyor weighing and proportioning equipment.

The Spanish government has approved the formation of a company to be known as **David Brown Engranajes S.A.,** which will undertake manufacture of commercial-vehicle gearboxes and gears in a new factory at present under construction at Villaverde, near Madrid.

Hilger & Watts Ltd. have acquired the whole of the issued share capital of **The Infra-Red Development Co. Ltd.,** of Welwyn Garden City.

Newton Chambers and Co. Ltd., of Thorncliffe, Sheffield, have entered into a licence agreement with the **Corner Tube Boiler Co. Ltd.,** of Manchester, for the production and sale of corner tube boilers in Great Britain.

The Compressor Division of **Demag, A.G.,** of Duisburg, Germany, have signed an agreement with **William H. Capper & Co. Ltd.,** of 8/9 Hertford Street, London, W.1, under which the British firm are appointed as sole representatives in the United Kingdom and Northern Ireland for the sale of all compressed air and mining equipment manufactured by Demag.

British hydraulic-equipment manufacturers formed a new organization, **"The Association of Hydraulic Equipment Manufacturers"** which will encourage and sponsor research for the benefit of the members, collect and distribute technical information, and advise on exhibitions at home and abroad. The offices of the association are at 38/40 Eccleston Square, London, S.W.1.

Aluminium Union Limited have, with effect from October 1, 1959, changed their name to **Alcan (U.K.) Limited.**

A new consortium of British companies, **Power Construction Limited,** of 19 Berkeley St., London, W.1, has been formed to design, manufacture, deliver, and construct power stations in any part of the world. The members of the consortium are: **The Armfield Hydraulic Engineering Co. Ltd., Belliss & Morcom Ltd., Cory Brothers & Co. Ltd., Lancashire Dynamo Holdings Ltd.,** and **Mitchell Engineering Group Ltd.**

Samuel Griffiths (Willenhall) Ltd., of Willenhall, Staffs., have been granted the sole manufacturing rights of the patented "Helicogir" strip-pickling plant throughout the U.K., Ireland, Australia, South Africa, and New Zealand, under licence from **Société Meusienne de Constructions Mécaniques,** of Ancerville (Meuse), France.

Research and Control Instruments Limited have become sole distributors in the United Kingdom for the industrial products previously marketed by their associated company, **Philips Electrical Ltd.**

CONTRACTS

The General Electric Co. Ltd., in association with **Vacuum Industrial Applications Ltd.,** have received an order from the **National Physical Laboratory** for a 2-litre vacuum arc-melting furnace. The furnace will be used for melting and casting refractory metals such as titanium, niobium, and molybdenum.

Platt Brothers (Sales) Ltd., a subsidiary of **Stone-Platt Industries Limited,** announce that they have received an order from the U.S.S.R. for cotton machinery valued at approximately £250,000.

A contract for diesel generating plant, which is to be installed by 1960 in the remoter parts of Nigeria, has been awarded to **Blackstone & Company Ltd.,** of Dursley, Glos., by the Nigerian Government.

Elliott Brothers (London) Limited, a member of the **Elliott-Automation Group,** and **Siemens Edison Swan (Australia) Pty. Limited** announce that they have received orders to a value in excess of £120,000, for the supply and installation of electronic recording and control equipment for the Cockle Creek works of **Sulphide Corporation Limited,** of New South Wales.

An order worth over £1,000,000 for British "Staybrite" stainless steel has been placed with **Firth-Vickers Stainless Steels Limited,** of Sheffield, by the Chinese Peoples' Republic.

Electrical plant valued at £325,000 and comprising four 2000-hp d.c. motors and twenty-two mercury arc rectifiers will be supplied by the Heavy Plant Division (Rugby), of **Associated Electrical Industries Ltd.** for a new 56-in., reversing cold-strip mill at the Shotton Works of **John Summers & Sons Ltd.**

PHILLIPS
RECESS
METAL THREAD SCREWS
ANOTHER H. & S. AID TO INDUSTRY!
Speed up production with Phillips Recess Metal Thread Screws and Slotted Indented Hexagon head Machine Screws.
'THE SCREW WITH THE ALTERNATIVE DRIVE.'
INDENTED
HEXAGON HEADS
THOS. HADDON & STOKES LTD.
DERITEND BIRMINGHAM 12

Do you wait for hot water on a cold Monday morning?

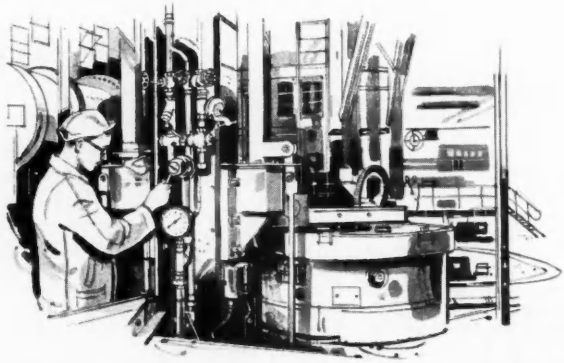
Where hot water is provided from a storage system there is a waiting period when production starts, for the water to heat up in the storage tanks.
With Leonard Steam Water Mixers there is no waiting period. Hot water is available as soon as the steam is turned on.

How would you raise the temperature of a spray very gradually from cold to 120 degrees?

Leonard Valves fitted to the sparge pipe on a cloth scouring and milling machine enable the scourer to vary the temperature to suit the work and to make changes in the temperature during the process gradually, giving a cleaner scour and a better finish.

Do you use cold water when you would like to use hot?

When vegetables are cleaned for canning they are washed in a running stream of water. If the water is too cold the girls' fingers get numb and their production slows down. If it is too hot the vegetables are spoilt. A Leonard Valve looks after the temperature, the girls' fingers and the vegetables.



These are specific examples. Your use of Leonard Thermostatic Steam Water Heaters will probably be different. Write for help. (Our folder H/24)

WALKER CROSWELLER & CO. LTD.

Cheltenham. Telephone 56317

An order for the building of a 68-in. semi-continuous hot strip mill for the Ravenscraig Works of **Colvilles Limited** has been placed with **Davy and United Engineering Company Limited,** of Sheffield. The value of the contract exceeds £4,000,000.

INTERNATIONAL DIE-CASTING CONFERENCE

Under the auspices of the European Pressure Die-Casting Committee, the third International Pressure Die-Casting Conference is being organized by the Italian member of the secretariat, the Instituto Italiana del Piombo e dello Zinco, with the help of the pressure die-casting section of Assomet (National Association of Non-Ferrous Metal Industries). The conference, which will be held at Stresa from May 16 to 20, will include displays of the world's leading die-casting-machine manufacturers and an exhibition of zinc, aluminium, and magnesium-alloy castings. Two days will be devoted to works visits and two days to technical sessions, the papers presented being available in four official languages, i.e., in French, German, Italian, and English.

Enrolment forms and preliminary programmes can be obtained from the Zinc Development Association, 34 Berkeley Square, London, W.1.

INAUGURATION OF WILLINGTON A POWER STATION

The Willington "A" power station of the Central Electricity Generating Board was officially opened last month. This is the first station to use English Electric's 100,000-kW fully direct hydrogen-cooled alternator, which has been installed in the No. 2 unit. The hydrogen-cooled alternator is of the same size as the other three units, and has been installed to provide early operating experience of the new cooling technique which is now being adopted for machines of much larger rating.

NEW METALLURGICAL DEPARTMENTS FOR THE HOLMAN GROUP

New metallurgical-equipment and heat-treatment departments have been installed at the headquarters of the Holman Group at Camborne, Cornwall. The departments, which have a floor area of 17,000 sq ft, contain metallurgical, physical, and chemical laboratories and high-speed, tool-steel, piston, and general heat-treatment sections. The metallurgical department works in close association with the production departments and tackles all kinds of day-to-day problems, such as machinability and routine metallographic examinations of heat-treatment processes. In the adjoining heat-treatment department, heat-treatment of high-speed steels, high-alloy steels, and tool steels is carried out, while a general section deals with operations involving annealing, normalizing, carburizing, hardening, and tempering of constructional case-hardening steels.

PROGRESS OF BRADWELL NUCLEAR POWER STATION

Construction of the 300-MW Bradwell nuclear power station started early in 1957 and the work is to be completed by the end of 1961. Designed and erected by The Nuclear Power Plant Company Limited, the power station comprises two carbon dioxide cooled graphite-moderated reactors supplying heat to twelve boilers. To date, construction of the first reactor, with its six boilers, has nearly been completed, and arrangements are being made for pressure-testing the spherical pressure vessel. Building of the second reactor is well under way, five of the six boilers being already installed. The turbine house, which will accommodate six main and three auxiliary turbo-alternators, is structurally complete, and the first turbine has been installed. Work is nearing completion on the pumphouse, circulating-water system, cooling pond, and carbon dioxide storage plant.

A remarkable feature of the erection was the transport of the twelve huge heat-exchanger vessels, each nearly 100 ft long and weighing 200 tons, from the Thornaby-on-Tees works of Head Wrightson & Co. Ltd. to the site of the power station at the Black Water Estuary by a 300-miles sea route, thereby avoiding congestion in transport and other problems which would have been created by conventional road or rail transport of these vessels.

Classified Advertisements

The rate for all classified advertisements is 9d. per word : in bold print 1s. per word : minimum order 10s. Box-number advertisements 1s. extra. Semi-displayed advertisements on this page 60s. per single column inch. Instructions, together with remittance, must be received not later than the 1st of each month for advertisements to appear in the same month's issue.

WANTED

Wanted. Representatives for correspondence abroad, high earnings, written instructions. Write: Fortuna Publishing Co., Vienna 1/8, Postfach 49.

BALL AND ROLLER BEARINGS, Etc. WANTED. Also Surplus Goods—Especially Hand Tools—of all descriptions. **R. Pordes,** 138 New Cavendish Street, London, W.1. MUSeum 5250.

ENGINEERING INSTRUCTOR required at our Senior Approved School for boys between 15 and 19 years. Experience in teaching senior boys an advantage.

Salary for qualified man, Burnham scale plus four increments, with an additional payment of £189 per annum for extraneous duties.

House available for married man.

Applications (no forms), with copies of two testimonials and names and addresses of three referees, to the Headmaster, Norton School, Kineton, Warwicks.

PRESSURE DIECASTINGS

JOHN IRELAND (WOLVERHAMPTON) Ltd.
Bilston Street, Wolverhampton.
Telephone: 22134

SHIPPING AND FORWARDING AGENTS
HENRY JOHNSON SONS & Co. (U.K. Branches) LTD.

LIVERPOOL	MANCHESTER	LONDON E.C.3
19, Castle Street	Travis Street	41, Trinity Square
Phone: Central 3352-6183	Phone: Ardwick 3245-6	Phone: Royal 2487-8

OSMOND

CUTTING OFF MACHINES

A. & S. OSMOND, LTD.
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Telephone: Bristol 27604

Anderton **CIRCLIPS**

CATALOGUE from ANDERTON SPRINGS Ltd. (A2) BINGLEY 2388
London Office: HOLborn 5151

HAWKER SIDDELEY BRUSH TURBINES LT

are pleased to announce that the

NEW TURBINE FACTOR

at HUCCLECOTE, GLOUCESTER

has now commenced manufacture of the following products

STEAM TURBINES

GAS EXPANSION TURBINES FOR USE WITH FREE PISTON GASIFYERS

GAS COMBUSTION TURBINES

TURBOCHARGERS FOR DIESEL ENGINES

Literature for these products is available on request

Many of our customers will already have received notification of this new factory and will be aware that those turbo-type products previously manufactured by Brush Electrical Engineering Co. Ltd. at Loughborough are now being made in a factory specially laid out for turbo-type machines. Thus, the cumulative experience of over 50 years of turbine building is now concentrated in a modern factory equipped with up-to-date research and development facilities.

Specialist engineers are available to render any assistance in the matter of selection, installation and maintenance of our products.

Service, Spares and Repairs

We would emphasize that this new Company will continue to provide those services hitherto provided by Brush Electrical Engineering Co. Ltd. at Loughborough.

HAWKER SIDDELEY BRUSH TURBINES LTD.

HUCCLECOTE, GLOUCESTER TELEPHONE: GLOUCESTER 67031

TELEGRAMS: TURBINES, GLOUCESTER. TELEX

A Member of the Hawker Siddeley Group

G 1

NEW TECHNICAL BOOKS

Ground Water Hydrology. By David Keith Todd, Ph.D. 348 pp., 156 illustrations. Publishers: John Wiley & Sons, Inc., New York, and Chapman & Hall Ltd., 37 Essex Street, London, W.C.2. Price: 86/–.

Presupposing only a background of mathematics as far as calculus and an elementary knowledge of geology, this well-written and produced book provides a unified and comprehensive account of the fundamentals and recent methods and problems encountered in the field of ground-water hydrology. At the same time, although the book has been restricted to a practical size, its scope has in no way been impaired.

In addition to reporting on the future role of ground water as a major water-supply source in the U.S.A. as the result of expanding population rates, increased industrialization, and the greater individual use of water, the book deals with a number of problems, including the control of seawater in wells near the coast, and the dangers of pollution of ground water from such sources as sewage, brines, industrial wastes, and nuclear power plant. In addition, consideration is given to problems related to the location of ground-water supplies, the construction of wells, and the determination of how much water they will yield, and to the determination of the amount of water that can be pumped from wells located near each other or near streams.

Introduction to Plasticity. By William Prager. 156 pp., 82 illustrations. Publishers: Addison-Wesley Publishing Company, Inc., Reading, Mass., U.S.A., and 10-15 Chitty Street, London, W.1. Price: 49/–.

Based on a series of lectures given by the author at the Federal Polytechnic Institute in Zürich and originally published in German in a Swiss edition in 1955, this book supplements traditional texts on the strength of materials and the theory of structures, which are primarily concerned with elastic behaviour. By restricting the scope of the book to selected topics from the theory of perfectly plastic solids, Professor Prager makes it possible for readers to approach the frontiers of current research without presupposing any prior familiarity with the subject. In fact, as he points out in his preface, much of the material presented is of fairly recent origin and is thus not found in standard reference works.

By the skilful use of simplified stress-strain relations to describe idealized rigid-plastic or elastic-plastic behaviour, Professor Prager makes it possible to obtain clear results for plates, frames, and shells, as well as for trusses and beams. For convenience, the book has been divided into four chapters, covering respectively the mechanical behaviour of plastic solids, the mechanical behaviour of plastic structures, limit analysis and design, and finite plastic deformations, in which indications are given as to how results can be applied to such forming processes as extruding, rolling, and drawing.

The Physical Metallurgy of Rolling. By F. H. Scott, B. Met., Ph.D. 102 pp., 19 illustrations. Publishers: Arthur H. Stockwell Limited, Elm Court, Ilfracombe, Devon. Price: 10/6.

Rolled materials may be considered as perhaps the most important single class among available metal materials which are fabricated into finished articles, and this well-produced and written little volume admirably serves to stimulate observation and interest in rolling phenomena. The treatment, although technical in parts, is not too difficult to be understood by those interested in the subject, and the book therefore assists as a transmitter of old and new knowledge between rolling, metallurgy, and physics. In short, this interesting book is a condensation of knowledge of the behaviour of metals, when rolled, into information which can then be generalized into practical data for steelmakers and engineers.

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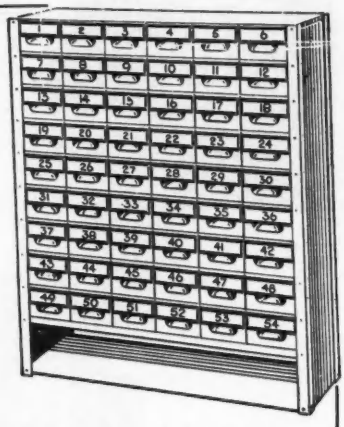

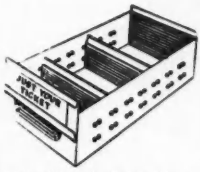

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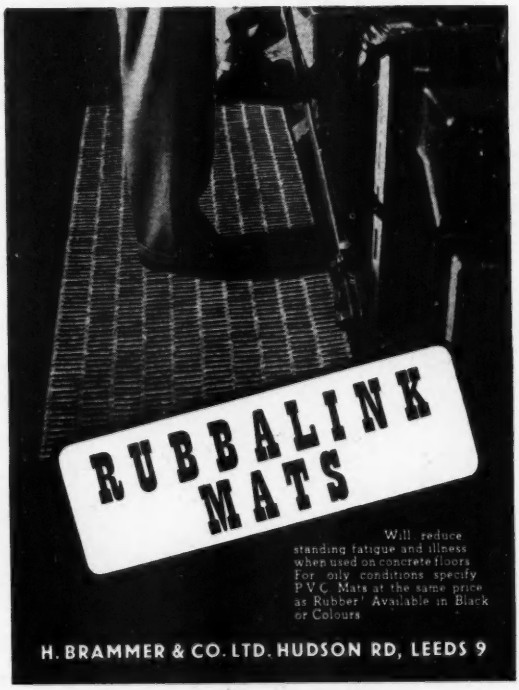
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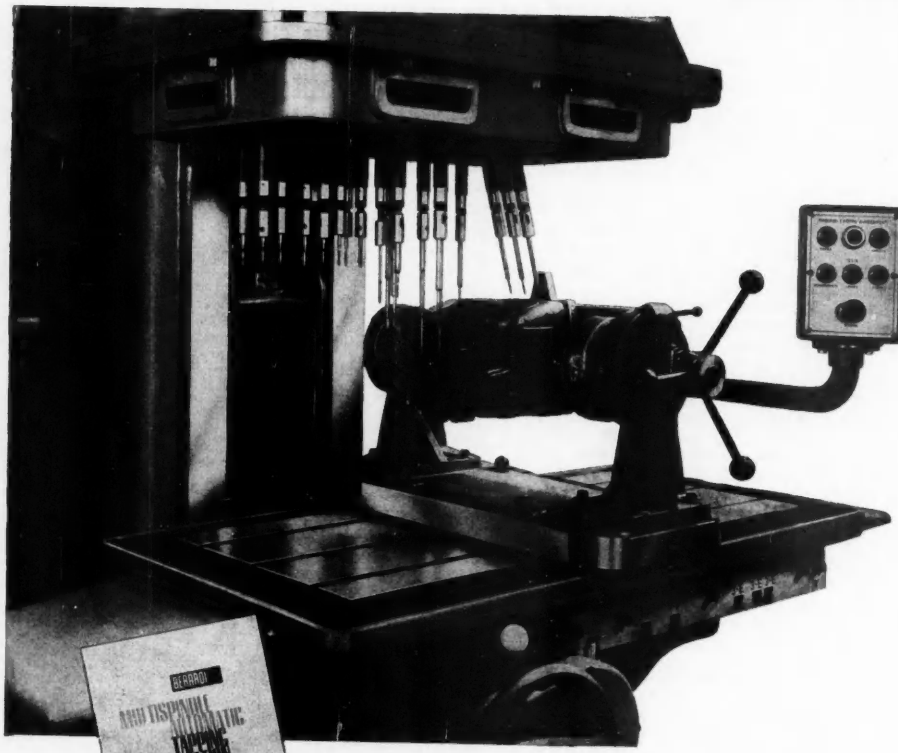

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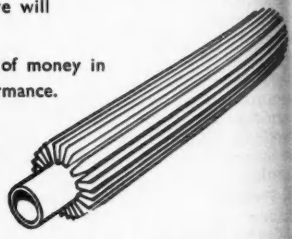

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